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Österreichische Akademie
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INSTITUT FÜR
TECHNIKFOLGEN-
ABSCHÄTZUNG

SYSTEMS BIOLOGY IN AUSTRIA 2011

**THE ESTABLISHMENT OF A NEW FIELD
IN A NATIONAL CONTEXT**

PROJECT REPORT

ITA-PROJEKTBERICHT NR. C28

ISSN: 1819-1320

ISSN-ONLINE: 1818-6556





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Austrian Academy
of Sciences



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INSTITUTE OF TECHNOLOGY ASSESSMENT
OF THE AUSTRIAN ACADEMY OF SCIENCES

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STUDY, FUNDED WITHIN THE AUSTRIAN GENOME RESEARCH PROGRAMME
GEN-AU BY THE AUSTRIAN MINISTRY FOR SCIENCE AND RESEARCH, BMWF

VIENNA, APRIL 2012

MASTHEAD

Owner:

Austrian Academy of Sciences
Legal person under public law (BGBl 569/1921 idF BGBl I 130/2003)
Dr. Ignaz Seipel-Platz 2, A-1010 Vienna

Editor:

Institute of Technology Assessment (ITA)
Strohgasse 45/5, A-1030 Vienna
<http://www.oeaw.ac.at/ita>

The ITA Project Reports are published irregularly and publish the research results of the Institute of Technology Assessment.

The Reports are published in print in small numbers only and are made available to the public via the Internet portal "epub.oeaw":

<http://epub.oeaw.ac.at/ita/ita-projektberichte>

ITA Project Report No.: c28

ISSN: 1819-1320

ISSN-online: 1818-6556

<http://epub.oeaw.ac.at/ita/ita-projektberichte/e2-2c28.pdf>

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Summary

This report is embedded in the larger research project ‘Towards a Holistic Conception of Life? Epistemic Presumptions and Socio-Cultural Implications of Systems Biology’, conducted jointly by the Institute of Technology Assessment at the Austrian Academy of Sciences and the Research Centre for Biotechnology, Society, and the Environment (FSP BIOGUM) at the University of Hamburg.

It gives a first overview of the state of establishment and institutionalisation of systems biology in Austria in 2011. It is based upon a methodical investigation of scientists, institutions, research projects, university courses and publications making use of the term ‘systems biology’ in this national context and puts an emphasis on the completeness and reproducibility of the reported results. The most relevant institutions are enlisted along three categories and shortly characterised.

Overall, the state of establishment of systems biology is much less advanced than in Germany, the United Kingdom or Switzerland. It takes place on a smaller scale and is driven by a more cautious attitude. Also, it takes place in a more diverse and fragmented mode. Only a few, small institutes carry the label in their name and systems biology is (at least as a label) almost absent in university curricula.

The rightful attribution or meaning of the label ‘systems biology’ is not questioned at this point; rather, different configurations of doing systems biology are addressed tentatively by co-authorship analyses, discipline-based categorisations, historical timelines and geographical analyses. Moreover, general problems relating to such an early onwards assessment of the state of a new scientific field are discussed in the introduction.

Acronyms, abbreviations and synonyms

(See also the annex for full titles of EU project acronyms.)

AIT	Austrian Institute of Technology
APP	Austrian Proteomics Platform
Austrian Council for Research and Technology Development ...	Rat für Forschung und Technologieentwicklung
Austrian Science Board ...	Österreichischer Wissenschaftsrat
BIN	Bioinformatics Integration Network
BMVIT	Austrian Federal Ministry for Transport, Innovation and Technology, Bundesministerium für Verkehr, Innovation und Technologie
BMWF	Austrian Federal Ministry for Science and Research, Bundesministerium für Wissenschaft und Forschung
BMWFJ	Austrian Federal Ministry of Economy, Family and Youth, Bundesministerium für Wirtschaft, Familie und Jugend
BOKU	University of Natural Resources and Life Sciences, Universität für Bodenkultur Vienna
CeMM	Research Center for Molecular Medicine at the Austrian Academy of Sciences
COSB	Center for Organismal Systems Biology at the University of Vienna
ERA-NET	European Research Area NET; EU scheme for organising cooperation and coordination of research activities carried out at national or regional level in member states and associated states; includes the two initiatives ERASysBio and SysMO (http://cordis.europa.eu/coordination/era-net.htm , accessed April 2 nd , 2012)
ERASysBio ...	ERA-NET initiative with the mission “to carry out fundamental and strategic collaboration in the funding of systems approaches to biological research” (http://www.erasysbio.net/ , accessed April 2 nd , 2012)
FFF	Forschungsförderungsfonds für die gewerbliche Wirtschaft’, since 2004 subsumed in the FFG
FFG	Austrian Research Promotion Agency, Österreichische Forschungsförderungsgesellschaft
FP6, FP	Sixth and Seventh Framework Programme of the EU
FWF	Austrian Science Fund, Fonds zur Förderung der wissenschaftlichen Forschung
GEN-AU	FFG funding programme ‘Genome Research in Austria’, FFG Förderprogramm ‘Genomforschung in Österreich’
Graz University of Technology ...	also: Technische Universität Graz
IMBA	Institute of Molecular Biotechnology at the Austrian Academy of Sciences, Institut für Molekulare Biotechnologie der Österreichischen Akademie der Wissenschaften
IMGuS	Institute for Medical Genome Research and Systems Biology

- IMP** Research Institute of Molecular Pathology
- Innsbruck Medical University** ... also: Medizinische Universität Innsbruck
- IST Austria, ISTA** ... Institute of Science and Technology Austria
- ITA** Institute of Technology Assessment,
Institut für Technikfolgen-Abschätzung
- JKU** Johannes Kepler University Linz,
Johannes Kepler Universität Linz, University of Linz
- KFU** Karl-Franzens-Universität Graz, University of Graz
- MFPL** Max F. Perutz Laboratories
- MUW** Medical University of Vienna, Medizinische Universität Wien
- ÖAW** Austrian Academy of Sciences,
Österreichische Akademie der Wissenschaften
- ÖGSB** Austrian Society of Systems Biology,
Österreichische Gesellschaft für Systembiologie
- Oncotyrol** Center for Personalized Cancer Medicine
- RICAM** Johann Radon Institute for Computational and Applied
Mathematics at the Austrian Academy of Sciences
- SCCH** Software Competence Center Hagenberg
- SysMO** ERA-NET funding and research initiative on ‘Systems Biology
of Microorganisms’ (<http://www.sysmo.net/>,
accessed April 2nd, 2012)
- TU Vienna** ... Vienna University of Technology,
Technische Universität Vienna
- UNIT** The Health and Life Sciences University Hall/Tirol
(private Universität für Gesundheitswissenschaften,
medizinische Informatik und Technik Hall/Tirol)
- University of Graz** ... also: Karl-Franzens-Universität Graz, KFU
- University of Innsbruck** ... also: Leopold-Franzens-Universität Innsbruck
- University of Linz** ... also: Johannes Kepler University Linz,
Johannes Kepler Universität Linz, JKU
- University of Salzburg** ... also: Universität Salzburg
- VU Vienna** ... University of Veterinary Medicine Vienna, Vetmeduni Vienna,
Veterinärmedizinische Universität Vienna
- WWTF** Vienna Science and Technology Fund,
Wiener Wissenschafts-, Forschungs- und Technologiefonds

I Introduction: systems biology as a new label

Around the turn of the last century, systems biology has established itself as a new and prominent research label within the life sciences. The number of publications featuring ‘systems biology’ as a keyword has increased steadily from four in the year 2000 to 1.362 in the year 2011 (Web of KnowledgeTM database¹, Figure 1). The relative frequency of such papers shows the same steady increase with a stabilising trend since 2011.²

**‘systems biology’ in
scientific publications**

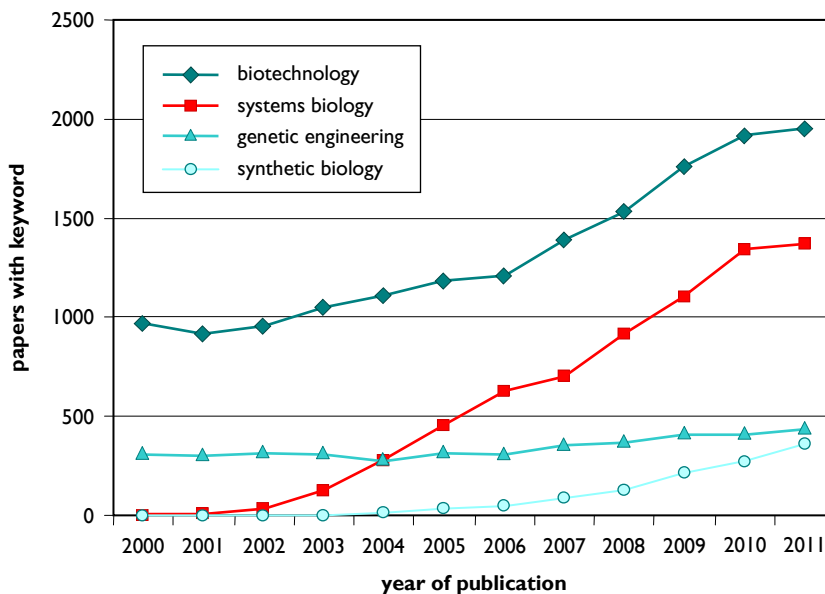


Figure 1: Papers in Web of KnowledgeTM database with topic ‘biotechnology’, ‘systems biology’, ‘genetic engineering’ or ‘synthetic biology’ (as of March 5th, 2012)

The increased use of the term in scientific publication databases has been accompanied by the promotion of systems biology research via specific funding programmes and its institutionalisation via new research centres. Hot spots of such systems biology funding and founding activities include the USA, Great Britain and Germany.

The US National Institutes of Health (NIH) currently support thirteen *National Centers for Systems Biology*, including the *Center for Systems Biology* (*2006) at the *Institute of Systems Biology* in Seattle, Washington (*2000), the *Center for Systems and Synthetic Biology* at the University of California San Francisco (*2010), the *Center for Complex Biological Systems* at the University of California (*2001), Irvine, the *Chicago Center for Systems Biology*, the *Duke Cen-*

**systems biology research
centres and institutes
in the US**

¹ <http://apps.webofknowledge.com>, search for topics, March 13th, 2012.

² One methodological *caveat* has to be considered here: although absolute (papers with keyword per year) and relative (papers with keyword divided by total number of papers per year) frequency curves do not differ fundamentally in their shape, the observable general tendency of such curves to show upward trends could be the result of rising numbers of keywords per paper over time. Still, counter-examples can be found, like for instance for the topics ‘chromosome’ or ‘transduction’.

**systems biology research
centres and institutes
in the UK**

ter for Systems Biology (*2007), the San Diego Center for Systems Biology (*2010) and the Systems Biology Center New York.³

In a joint effort, the Biotechnology and Biological Sciences Research Council (BBSRC) and the Engineering and Physical Sciences Research Council (EPSRC) funded six *Centres for Integrative Systems Biology* (CISBs) in the United Kingdom in two rounds in 2005/6: the *Centre for Integrated Systems Biology of Ageing and Nutrition* (CISBAN) at Newcastle University, the *Centre for Integrative Systems Biology at Imperial College* (CISBIC) at Imperial College London, the *Manchester Centre for Integrative Systems Biology* (MCISB) at the University of Manchester, the *Centre for Systems Biology at Edinburgh* (CSBE) at the University of Edinburgh, the *Centre for Plant Integrative Biology* (CPIB) at the University of Nottingham and the *Oxford Centre for Integrative Systems Biology* (OCISB) at the University of Oxford.⁴ A 2007 report by the Academy of Medical Sciences and The Royal Academy of Engineering (Academy of Medical Sciences and The Royal Academy of Engineering 2007: 34) lists a total of sixteen systems biology centres in the UK.

**systems biology research
centres and institutes
in Germany**

In Germany, the Federal Ministry of Education and Research (BMBF) launched a call for proposals entitled 'Systems of Life – Systems Biology' in 2001 and initiated the pilot project HepatoSys, that was followed up by the Virtual Liver Network and has "since developed into an internationally recognized network of expertise on the 'liver system model'"⁵. In 2007, four FORSYS centres were established, the *Freiburg Initiative for Systems Biology* (FRISYS), Go-FORSYS in Potsdam-Golm, VIROQUANT (systems biology of virus-cell interactions) and the *Magdeburg Centre for Systems Biology* (MaCS). Further funding has been targeted at a systems biological research focus on ageing (GerontoSys), at medical systems biology (MedSys, *Berlin-Institute for Medical Systems Biology*, *Medical Systems Biology Charité*) and a few further initiatives (cp. Brüninghaus and Kastenhofer 2012).

**systems biology research
centres and institutes
in Austria**

Compared to these substantive and pronounced efforts, the situation in Austria is much more modest. Mission-oriented funding targeting systems biology was restricted to the FFG-initiative GEN-AU (Austrian Research Promotion Agency, 2001-2012),⁶ in which systems biology played an increasing but not a central role and which will end in 2012, most likely without replacement. The Austrian Science Fund (FWF), dedicated to bottom-up funding of fundamental research, mentions only one transnational and three national research projects with 'systems biology' as a key word.⁷ Major research networks or institutes do not feature under this label. Moreover, scientists seem to be more reluctant to take up the new term when characterising their research and depicting their own affiliation. Currently, one research centre – although not advertising it in its name – is perceived as a systems biology research institution within the national and international scientific community (CeMM – *Centre for Molecular Medicine*). Additionally, two chairs at the University of Vienna (for *Computational Systems Biology* and *Molecular Systems Biology*) and a few research groups run under the label of 'systems biology' (see the detailed list in chapters 5, 6 and 7).

³ <http://www.systemscenters.org/>, accessed March 5th, 2012.

⁴ <http://www.bbsrc.ac.uk/organisation/institutes/systems-biology-centres.aspx>, accessed March 5th, 2012.

⁵ <http://www.systembiologie.de/en/information.html>, accessed March 5th, 2012.

⁶ The Vienna Science and Technology Fund (WWTF) also funded one 'Life Science Chair' in 2004, devoted to bioinformatics and systems biology research.

⁷ http://www.fwf.ac.at/de/projects/projekt_suche.html, as of March 5th, 2012.

Austria also participates in systems biology projects funded within the EU framework programmes 6 and 7⁸ and in EU ERA-NET activities, the SysMO initiative on the ‘Systems Biology of Microorganisms’⁹ and the ERASysBio initiative, “a consortium of funding bodies, ministries and project management agencies” with the mission “to carry out fundamental and strategic collaboration in the funding of systems approaches to biological research.”¹⁰ Here again, the relatively low level of participation mirrors a currently low level of institutionalisation of systems biology in Austria.

A search in the EU research framework database¹¹ results in 72 FP-6¹² and 259 FP-7¹³ projects mentioning ‘systems biology’ in title, abstract or keyword.¹⁴ Of the 67 projects funded within FP-6, none is coordinated and seven are contributed to by Austrian research groups; of the 29 projects funded within FP-7, two are coordinated and one is contributed to by Austrian research groups. An overview is presented in Figure 2.

Austria's share in EU funded systems biology research

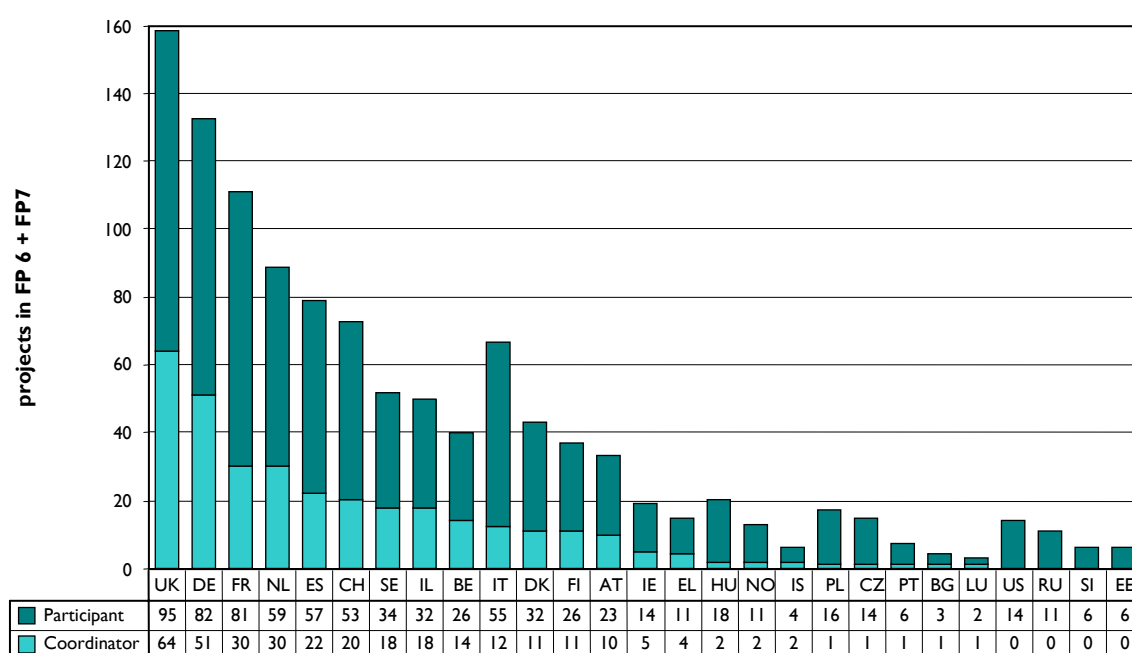


Figure 2: Number of FP-6 and FP-7 projects coordinated and participated in per country (multiple participation per country is not noted)

⁸ Earlier programmes did not include research projects mentioning systems biology, with one exception in FP 5: ‘Open Reading Frames for the European Union Scientists’ (ORFEUS), a LIFE QUALITY project coordinated by the Dpt. of Plant Systems Biology at the Flanders Interuniversity Institute for Biotechnology (VZW).

⁹ <http://www.sysmo.net/>, accessed April 2nd, 2012.

¹⁰ <http://www.erasysbio.net/index.php?index=311>, accessed March 5th, 2012.

¹¹ <http://cordis.europa.eu/search/index.cfm?fuseaction=proj.advSearch>, accessed March 13th, 2012.

¹² The acronyms of these projects are listed in the annex.

¹³ The acronyms of these projects are listed in the annex.

¹⁴ This kind of search does not discern mere mentioning of systems biology from a fundamental orientation towards systems biology. Hence, the overall number of systems biology projects has to be taken with caution.

Of the 20 ERASysBio+ projects¹⁵, Austria participates in only one project. The ERASysBio+ initiative “brings together funding agencies from 13 countries including Israel and Russia.” Luxembourg and Switzerland joined later as affiliated partners.¹⁶ An overview of all countries participating in ERASysBio+ projects is given in Figure 3.

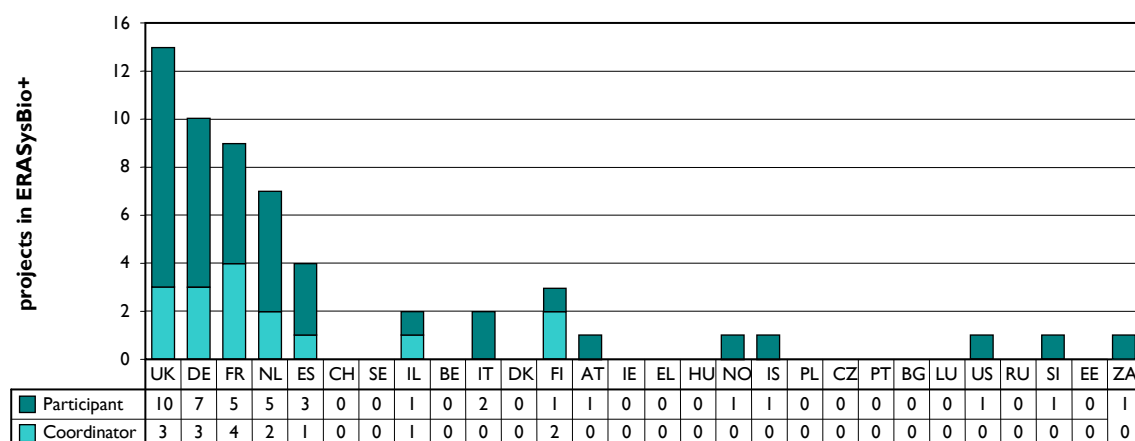


Figure 3: Number of ERASysBio+ projects coordinated and participated in per country (multiple participation by more than one research group per country is not noted)

Of the 19 projects funded within the SysMO programme, Austria participates in only two (see Figure 4). This is especially remarkable because Austria was one of only six countries co-funding this initiative (besides Germany, the Netherlands, Norway, the United Kingdom and Spain). Austria also ‘inherited’ one coordinator position when the principal investigator of SulfoSYS moved from Norway to Austria around 2007 (not depicted in Figure 4).

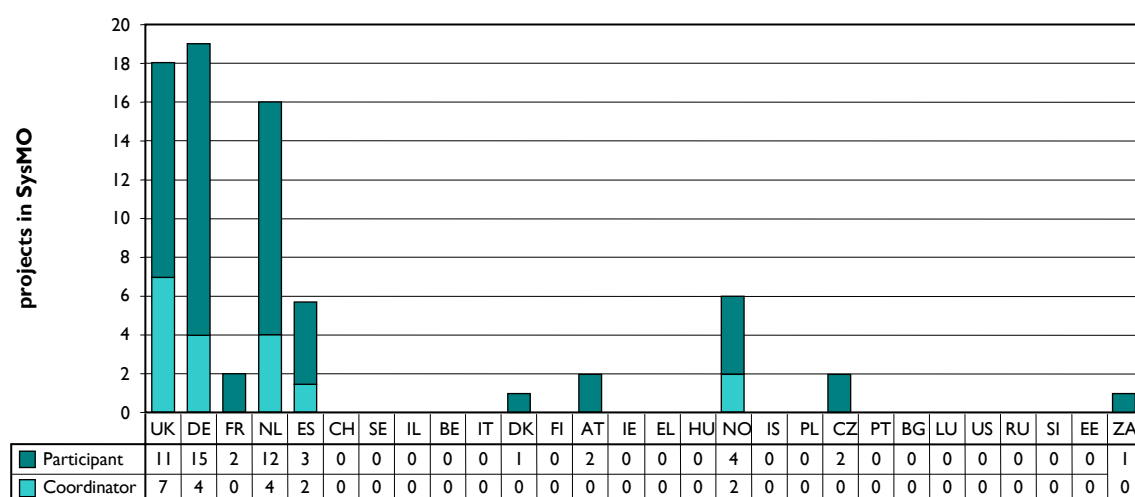


Figure 4: Number of SysMO projects coordinated and participated in per country

¹⁵ The acronyms of these projects are: FRIM, LINCONET, BioModUE PTL, Zebrain, Synergy, SynProt, LymphoSys, SHIPREC, ModHeart, C5Sys, iSAM, livSYSiPS, EpiGenSys, GRAPPLE, ApoNET, TB-HOST-NET.

¹⁶ <http://www.erasysbio.net/Summary>, accessed April 4th, 2012.

Austrian policy documents and plans to institutionalise systems biology in Austria show that the interest in systems biology has already been more pronounced than it is now.

Already in 2000, the *Research Center for Molecular Medicine* (CeMM) of the Austrian Academy of Sciences was established. Although it is widely perceived as contributing to systems biology research and has gained high international recognition, it does not feature systems biology in its title.

The *Austrian Council for Research and Technology Development* (Rat für Forschung und Technologieentwicklung, “consulting the Austrian Federal Government in all issues of research, technology and innovation policy”¹⁷) in its 2005 strategy for the development of the life sciences in Austria mentions “systems biology/quantitative and computational bio-medicine” and the then planned *Institute for Medical Genome Research and Systems Biology* (IMGuS) as an example for how new, national fields of competence can be established successfully. Systems biology is also mentioned as a field of research where a need for catching up is attested (Rat für Forschung und Technologieentwicklung 2005a). In its ‘Strategy 2010’ (Rat für Forschung und Technologieentwicklung 2005b) the envisioned IMGuS is mentioned as one of three leading biotechnology research institutes worldwide (ibid: 24). The plan to establish IMGuS as a major Austrian research centre was later abandoned due to a lack of funding resources – a sudden lack of already assigned money explained by the necessity to spend it for the establishment of IST Austria (Ungerböck 2006a, 2006b). This also coincides with a general stagnation in science funding during this period and a related lack of uncommitted funds for new initiatives.

The *Austrian Science Board* (Österreichischer Wissenschaftsrat, the “main advisory body to the Federal Minister of Science and Research”¹⁸) in its statement on the ‘Austrian science’s excellence formation’ (Österreichischer Wissenschaftsrat 2007), mentions systems biology as one promising focus for the then newly planned *Institute for Science and Technology Austria* (IST Austria, inaugurated in 2009), because it links to existing research in Austria, but also complements it in important aspects with a view to international developments (ibid: 3). Two years later (Österreichischer Wissenschaftsrat 2009), the board’s recommendations for the Austrian higher education and science system mention the establishment of theoretical systems biology at an extra-university institute in the first half of the 20th century (one of the scarce references to systems biology’s Austrian forerunners in policy documents and media) as well as the present-day computational and molecular systems biology institutes and the *Center for Organismal Systems Biology* (COSB) at the University of Vienna. They criticise the structural heterogeneity and dispersion of life science research in Vienna and recommend further integration, but do not promote any specific line of research (like for instance systems biology).

In 2010, the *Austrian Federal Ministries of Science and Research* (BMWF), *for Transport, Innovation and Technology* (BMVIT) and *of Economy, Family and Youth* (BMWFJ) commissioned an Austrian Research and Technology Report (Schibany et al. 2010). This report mentions systems biology as a life science research field in which Austria participates in an ERA-NET and in transnational initiatives (medical systems biology and ELSA-GEN). The establishment and further integration of systems biology in Austria are also mentioned as goals for the second and third phase of GEN-AU (ibid: 157-158). However, the label ‘systems biology’ did not gain a very prominent role in

**systems biology
in Austrian policy
documents**

¹⁷ http://www.rat-fte.at/home_en.html, accessed April 11th, 2012.

¹⁸ <http://www.era.gv.at/space/11442/directory/11818.html>, accessed April 11th, 2012.

epistemic and socio-cultural implications of systems biology

the later phases of GEN-AU. Neither the web presentation nor project titles feature systems biology prominently, although some of the activities funded by GEN-AU are viewed as systems biology research or as contributions to establishing such an approach by relevant experts (like, for instance, the *Bio-informatics Integration Network*, see chapter 6). The GEN-AU initiative itself will end in 2012 without (foreseeable) replacement, thereby abandoning this line of ‘label-oriented’ (here: genomics-oriented) research funding.

The rapid establishment of the new label in the international scene, its great success in attracting funding and scientific interest in some countries and the observable national differences alone warrant a closer examination from a science studies point of view. Moreover, systems biology is often invested with the ability to revolutionise the life sciences¹⁹ and our understanding of nature, as well as to enable the precise modelling, simulation and engineering of living systems (the latter under the label of ‘synthetic biology’) and thereby to revolutionise societal contexts (in reference to the ‘Industrial Revolution’ or the ‘Green Revolution’²⁰). From a critical point of view (the perspectives of science and technology assessment or ‘ethical, legal and social aspects of science and technology’ research), it is a lack of terminological clarity (of the term ‘systems biology’ itself as well as of terms like ‘system’), the challenges raised by the prerequisite interdisciplinary collaboration (especially between *in vitro* and *in silico* sciences) as well as by other needs of integration (e.g., multi-level integration of genomics, proteomics, metabolomics, interactomics, etc.), standardisation issues, the quality of its output (proof of principle, re-affirmation of existing knowledge or fundamentally new insights), the feasibility of the envisaged approaches (like, for instance, whole-cell-modelling), their applicability in industry and medicine and the overall ‘Big Science’ approach pushed by some systems biology research initiatives (Krohs and Callebaut 2007, O’Malley and Dupré 2005, Vermeulen 2011). From a socioethics point of view, O’Malley et al. (2007) add a more detailed discussion of critical aspects of systems biology associated with *in silico* testing, cultural understandings of life, biological modification and commercialisation.

From the perspective of technology assessment, several potential applications of systems biology merit closer attention. Among these range

1. ***in silico* models developed for pharmaceutical drug development and toxicological tests:** such *in silico* models are the product of close collaborations between experimental life science research and *in silico* computation and modelling with a view to specific contexts of application. They raise critical questions about the kind, quality and applicability of knowledge produced via such *in silico* models. It is still under debate in how far *in silico* tests can replace tests run via test animals, in which ways they might be even more apt to draw conclusions concerning the toxicity of specific substances or treatments to humans and in which ways they might be less reliable or necessitate an adaption of the overall risk management regime in this context.
2. **A further expansion of *in silico* research in the life sciences** also exacerbates unsolved questions about property regimes at the intersection of biology and informatics. Biotechnology favoured patenting in the past, while computation and informatics feature a long-standing open source tradition. The combination of both precipitates decisions about where to apply which regulatory approach.

¹⁹ ERASysBio (2007) depicts systems biology as ‘biology’s Big Bang’.

²⁰ For instance in GEN-AU (2010: 5).

3. **Systems biology's close (if unclear) connection to synthetic biology** and the latter's ambition to 'create life from scratch' raises questions about the feasibility, desirability, safety, security, cultural meaning and acceptability of such claims and their realisation. The construction of living systems also blurs the boundary between what has so far been labelled as either nature or artefact and thereby raises questions about regulatory regimes.
4. **Systems biology's central role in the (projected) development of personalised medicine** triggers questions about the feasibility of such a personalised approach, the related organisational changes in the health system it necessitates, its cost efficiency, social justice, data handling and privacy.

Currently, most of these practical approaches are still in their infancy. A sound discussion of their feasibility, related best practices of innovation and possible concerns about unwanted side-effects is only possible if the current establishment and approaches of systems biology are understood in more depth. Moreover, systems biology – even if leading to no relevant applications in the near future – will leave its mark on the life science research landscape. A better understanding of its character and pattern of institutionalisation will help to reflect upon current shifts in academia and industrial research in national and international contexts.

The following report aims at contributing to these discussions by

- **providing a detailed list of current systems biology research groups, institutes, centres and university courses in Austria**, so as to render a more refined picture of its institutionalisation in this country, allow for a more informed observation of its further development in the national context and a more detailed comparison with other countries (chapters 5, 6, 7 and 8),
- **providing a list of systems biology experts in Austria**, so as to prepare for expert participation in future science and technology assessment initiatives,
- **addressing the interdisciplinary and collaborative character of systems biology research** by depicting the disciplinary affiliations of systems biologists in Austria and their positions in co-authorship networks (chapters 3 and 4),
- **putting the current stage of establishment of systems biology into context** by addressing relevant issues of investigating the establishment of emerging research fields (chapters 1 and 2).

The report presented here is based upon research conducted within the project 'Towards a Holistic Conception of Life? Epistemic Presumptions and Socio-Cultural Implications of Systems Biology' (THCL), performed by the Research Centre for Biotechnology, Society, and the Environment (FSP BIOGUM) at the University of Hamburg (coordinator) and the Institute of Technology Assessment (ITA) at the Austrian Academy of Sciences. It is co-funded by the German Federal Ministry of Education and Research (BMBF) and the Austrian Ministry for Science and Research (BMWF) within the transnational ELSA-GEN initiative (embedded in the Austrian FFG funding programme GEN-AU). Its Austrian sub-project ended in December 2011, whereas the German sub-project will last until April 2013, allowing for further empirical as well analytical work.

Empirical data are based upon a thorough web-based investigation of researchers, research projects, research institutes and research centres making use of the term 'systems biology'. These results were followed up by 38 semi-structured interviews and eleven informal conversations with experts in 2010 and 2011 (predominantly systems biology researchers in Austria, complemented by Austrian scientists from adjacent fields of research, Austrian sci-

general aims of investigating the establishment of systems biology in Austria

the project 'Towards a Holistic Conception of Life?' (THCL)

ence policy experts and systems biology researchers in the UK).²¹ Additionally, six systems biology symposia and conferences in Germany, the UK and Austria and two university courses were attended between September 2010 and February 2012.

While the main findings concerning the current state of systems biology in Austria are presented in this report, further analyses concerning more specific issues like interdisciplinary collaboration (cp. also Torgersen 2009) and community building within systems biology (Kastenhofer 2011, 2012), the relation of systems biology to science and engineering as well as to fundamental and applied research (Kastenhofer and Schmidt 2011a, 2011b), social aspects (Kollek et al. 2011, cp. also Kastenhofer 2010) and the governance of systems biology (Brüninghaus and Kastenhofer 2012) are (and will be) addressed in individual, peer reviewed journal papers. Ultimately, the transnational character of the underlying research project will allow for a more detailed comparison between systems biology in Austria and Germany.

Besides the authors Karen Kastenhofer, Helge Torgersen, Friederike Klein and Lea-Luise Klement, this report benefits from collaboration and exchange with Regine Kollek, Martin Döring, Anne Brüninghaus and Imme Petersen (FSP BIOGUM, University of Hamburg) and from all the expertise provided by our interview partners.

²¹ In this report, interview material is referred to in an anonymised mode, indicating the interview number (I 1, I 2, etc.).

2 General issues concerning systems biology and its establishment as a scientific field in a national context

The analysis of the establishment of systems biology in Austria has to face some challenges that come with its research object, systems biology. These shall be addressed here, referring to expert interviews, primary and secondary literature.

2.1 *Investigating the establishment of a field early onwards*

As mentioned above, the term ‘systems biology’ has begun to spread widely within the scientific community only about a decade ago. The current use of the term goes with a definition of systems biology as “applying systems theory to biology *in the postgenomic era*” (Wolkenhauer et al. 2003: 39). Only if the latter part of this definition is ignored, one can start to delineate a longer history which “involved eminent researchers including Wiener, Kalman, Bertalanffy, Rosen and Mesarovic in the 1960’s” (ibid.). Although former theoretical approaches are partly incorporated in recent research, it is the combination of systems theory, computational models and –omics approaches that defines current systems biology. It is not seen as a necessary starting point for present day and future systems biologists to be familiar with the work of Norbert Wiener, Ludwig von Bertalanffy or Robert Rosen.

Hence, one can safely say that the ‘new’ systems biology is rather young and cannot yet count as an established scientific field. Systems biology institutes have had – at most – ten years to establish their own organisational and collaborative routines, their modes of research and training. Systems biologists can still be differentiated along different ‘generations’: a first generation still embedded in one discipline, acknowledging that there might be something of interest at the intersection of disciplines and exchanging ideas with scientists from other disciplines; a second generation with a multidisciplinary career track and the ability to apply all the various disciplinary tools and knowledge themselves; and a third generation that has already followed a curriculum in systems biology.²² Moreover, some prefer to call themselves systems biologists while others prefer to label themselves along more traditional categories, but tag part of their work as ‘systems biology’; still others avoid the term altogether while admitting that their research could also be labelled as ‘systems biology’ and/or are seen as systems biologists by others (Kastenhofer 2012).

systems biology is not (yet) represented by a stabilised scientific community

As a result, there are multiple ‘ways of being’ within systems biology, of doing systems biology and of setting up a systems biology institute. This multiplicity can be explained by the early stage of the ‘new’ systems biology’s development as a research field. For Austria, it is safe to say that the new systems biology is in still earlier stages of institutionalisation than in other countries like the UK, Germany or Switzerland. During the years 2010 and 2011,

²² This differentiation was presented by one interviewed systems biologist (I 20).

when the empirical research for this project was conducted, the national institutional and collaborative landscape of systems biology changed a lot and – given the international success of the field – it is very likely that this development has not yet come to a halt. Therefore, the current report can only offer a preliminary account of the state of systems biology in Austria.

2.2 Investigating the establishment of a heterogeneous and interdisciplinary field

**the field of
systems biology is
not homogeneous**

Besides change over time, it is the heterogeneity of a field at a given time in history that challenges the analysis of its establishment. Systems biology is said to have different strands or sub-fields (like top-down, bottom-up and middle-out systems biology), it is defined in different ways by different scholars or schools (and discerned more or less rigorously from research that is *not* systems biology) and it is enacted in different ways by scientists stemming from different disciplines.

Within the expert interviews, heterogeneity is partly attributed to different local approaches. Specific research laboratories or institutes are seen as sites of specific schools, that then spread geographically. Heterogeneity is also connected to different research visions, research interests, research objects, research methods and to different (multi-)disciplinary arrangements.

This heterogeneity results in systems biology not so much resembling one highly integrated scientific community, but rather a differentiated field that meets at annual conferences and publishes in systems biology journals, but also meets at more specialised symposia and workshops and publishes in subgroup specific journals. The differentiation along different research traditions or schools also explains why systems biologists would mention very different names when asked about the most prominent colleagues within systems biology or about a list of every systems biologist they would be aware of in Austria.²³

In all cases, multi- or interdisciplinarity is seen as a defining feature of systems biology research; the minimum requirement being the combination of ‘wet’/‘experimental’ (biological, biochemical) and ‘dry’/‘theoretical’ (mathematical, computational) sciences. An important role is also attributed to informatics and (theoretical) physics. Finally, scientists trained in engineering fields – although not mentioned in the list of the most relevant disciplines – play a visible role within systems biology. Concerning the integration of ‘experimental’ and ‘theoretical’ sciences, systems biologists unequivocally advocate a symmetric relationship, void of hierarchically structured divisions of labour.

²³ Besides, most interviewees also stress that they lack an overview of systems biology in Austria.

2.3 Investigating the establishment ... of what?

Systems biologists often remark on the lack of a clear definition of systems biology. Other than 19th century subject matter definitions like ‘botany’ or ‘zoology’, or definitions that originated later onwards and determine the organisational level of interest like ‘molecular biology’, ‘cell biology’, ‘population biology’ or ‘ecosystem research’, systems biology is understood as research that makes use of a specific kind of data (namely -omics data) by specific means (quantitative modelling), drawing on experimental approaches (everything from medicine, to genetics, molecular biology and biochemistry) as well as theoretical approaches (mathematics, informatics) in a collaborative, interdisciplinary and iterative mode. Thereby, the definition of systems biology is far less specific concerning its subject matter (every biological entity can be represented as a system which would render ‘systems biology’ a tautology) but far more rigorous concerning its paradigms and research culture.

Hence, to define systems biology is not trivial, but possible if one refers to its various disciplinary backgrounds, its historical emergence (linking it to specific theoretical and technological breakthroughs), its concrete research practices and its general vision. Differences between existing definitions can be explained by different (sub)disciplinary audiences (the aim to explain systems biology to molecular biologists results in different emphases than the aim to explain systems biology to physiologists, mathematicians or computer scientists) and by different rigour.

Different rigour results in wider or narrower definitions. An example for a definition that can be understood as a very wide approach (that is, if the reference to time and space is not interpreted as a reference to very specific research methods) reads as follows: “Systems biology is a groundbreaking scientific approach that seeks to understand how all the individual components of a biological system interact in time and space to determine the functioning of the system.” (Academy of Medical Sciences and The Royal Academy of Engineering 2007: 5); whereas an example of a somewhat narrower definition has already been quoted above as “applying systems theory to biology *in the postgenomic era*” (Volkenhauer et al. 2003: 39). The definition given by the Academy of Medical Sciences and The Royal Academy of Engineering (2007: 5) also narrows down when adding that systems biology “allows insight into the large amount of data from molecular biology and genomic research, integrated with an understanding of physiology, to model the complex function of cells, organs and whole organisms, bringing with it the potential to improve our knowledge of health and disease.” Overall, the more dimensions are introduced in the definition, the more precise the boundary drawing becomes.

Definitions also differ in the importance they attribute to modelling as a *sine qua non* of systems biology research (cp. also Volkenhauer and Klingmüller 2004). Within a call for project proposals issued by the EU funding initiative ERASysBio, the definition holds that “[s]ystems biology is an approach by which biological questions are addressed through integrating experiments in iterative cycles with computational modelling, simulation and theory. Modelling is not the final goal, but is a tool to increase understanding of the system, to develop more directed experiments and finally allow predictions.” (ERASysBio 2008: 1-2) The Austrian annex to this call on the other hand does not mention modelling as a prerequisite component. Moreover, the Austrian GEN-AU funding initiative put more emphasis on bioinformatics in more general terms than on modelling in a stricter sense when targeting systems biology research.

**systems biology is
defined in different ways**

**what kind of category
is 'systems biology'?**

Much more complicated than defining systems biology is the task of understanding *what kind of category* 'systems biology' really represents. Is it a discipline, a sub-discipline, an inter-discipline, an approach, a vision, a paradigm or a way of doing science? All of these categories were mentioned in expert interviews; all of them would go with their own modes of definition, patterns of establishment and indicators of institutionalisation. Unfortunately, there exists no general agreement concerning this question in- or outside the scientific community. 'Research area' (Wolkenhauer et al. 2003) or 'field of research' (Wolkenhauer 2001) are just two terms that are broad enough to leave this question open.

To understand what kind of category systems biology represents, it is also helpful to discern different contexts in which definitions of scientific fields are developed and made use of. Classical categories like 'botany' or 'zoology' were established in an academic context to demarcate general topics various scientists worked on. Hence, these labels offer orientation via categorisation to scientists, lay-men looking for experts and students choosing their university curriculum. Outside universities and university curricula, such an absolute categorisation is less relevant.²⁴ Extra-mural research institutions can invent any new label to point at their innovative character and build upon multi- or interdisciplinary approaches as they think useful. This also pertains to the context of science funding.

**close relation of terms
like 'systems biology' to
R&D funding strategies**

To better understand labelling practices in research funding that become influential in the use of terms like 'systems biology', general trends within this context have to be kept in mind (cp. also Blümel 2011). Science funding or, more broadly, research and development initiatives, follow one of at least three different models:²⁵ *bottom-up basic research funding agencies* (research councils) like the Austrian FWF base their funding decisions on peer-review and individual quality assessment of each proposal; disciplinary categories play only an indirect role (e.g., the quality, availability or rigidity of reviewers may differ according to their disciplinary identity, thereby favouring some fields over others; multi- or interdisciplinary approaches may be discriminated due to a lack of reviewers who value interdisciplinary add-ons) as does the labelling of a research approach. *Mission-oriented funding bodies and programmes* (mission agencies) often define a general problem that should be solved or at least addressed by the funded research. Such missions link to Big Science contexts like the Manhattan project or the Human Genome Project, where specific outcomes like the building of the atom bomb or the deciphering of the humane genome were targeted. Mission oriented research is funded by national ministries within national and international funding initiatives (like some FFG initiatives in Austria or the EU frame work programmes) with an aim to encourage research that is otherwise neglected and promises to contribute to the common good (national competitiveness or societal sustainability). A third funding strategy seems to be a blend between the former two: funding initiatives target specific research fields or approaches with a more implicit or indirect link to a concrete mission. Such initiatives seem to be mostly *label-oriented* at first sight. This tradition is well illustrated by the U.S. based National Nanotechnology Initiative of the National Science Fund, but also by initiatives tar-

²⁴ Hence the saying "society has problems, universities have departments".

²⁵ The first and second model mentioned here represent the 'classical models'; the third model is newly introduced by the authors. Alternatively, one could also think of even more refined models or subsume 'label-oriented funding' under 'mission-oriented funding'. Interestingly, the third funding model stands for a targeted policy that is pursued by research councils or ministries. This combination runs counter to the twofold classification, along which research councils and ministries follow a *bottom-up* funding policy while *targeted* programmes are initiated by mission agencies.

getting systems biology or synthetic biology. The Austrian GEN-AU funding initiative by the FFG could be assigned to this category, targeting genomics.²⁶ The German BMBF initiatives targeting systems biology research also fall under this category. Earlier initiatives in Germany targeted fields like bionics, cybernetics and artificial intelligence (Aumann 2011).

It is against the background of a growing importance and impact of such label-oriented funding approaches that the emergence of terms like ‘systems’ or ‘synthetic biology’ can be better understood as will become even clearer in the following section. The use of terms like ‘systems biology’ not only points at a specific research approach, but also at a specific – namely a strategic funding – discourse; just like the use of the term ‘biotechnology’ not only invokes the idea of a specific research field but also a connection to technology-based innovation and industrial revolutions.

2.4 *Discussing the establishment of an actual research field, a label or a hype?*

Besides the fuzziness of the category ‘systems biology’, that challenges its epistemic value, there exists a general unease within the scientific community about its use. The general unease, with which the term ‘systems biology’ is sometimes met, is also directed to other terms like ‘synthetic biology’ (Nature Biotechnology 2009), ‘nanotechnology’ (Wullweber 2008) or ‘converging technologies’ (Coenen 2008).²⁷ Historians of science have also detected it for ‘cybernetics’ and ‘bionics’ (Aumann 2011). This unease is mirrored in accusations that systems biology was a mere ‘buzzword’ or, along the terminology of discourse theory, an ‘empty signifier’ (Wullweber 2008). Such accusations brand a strategic use of the term with political motives combined with a lack of meaning in a scientific context. They also refer to the power of hype-cycles within industrial and public funding policies. Hype-cycles are thought to be spurred by new terms that go with a revolutionary vision, while promising to solve the already established list of major societal problems (cancer, hunger, climate change and economic competitiveness).

It is the threefold reference to a lack of epistemic value, to political instrumentalisation and to an ever growing over-hyping within research and development fields that can render the use of the term ‘systems biology’ suspect. If the term is seen as a buzzword or at least as a label that only makes sense in the political, but not the epistemic sphere, than those who use the label to describe their research or their scientific affiliation are suspect; that is, under the assumption that science is a solely epistemic undertaking that has to be protected from social or political influences.

systems biology is seen as a (sub- or inter-) discipline, an approach, a vision, a paradigm or a ‘buzzword’

Wolkenhauer and Klingmüller (2004: 22) highlight a second cause why ‘systems biology’ might be criticised of buzzword-ism. “For any emerging area of research there is a risk that at some point in future it is looked at as a buzzword with all its negative connotations. There are two main causes for this to happen: individuals (mis)use the new term as a means to attract research fund-

²⁶ In Austria, label-oriented research funding seems not to be very popular among politicians as well as scientists.

²⁷ Terms like ‘molecular biology’ or ‘biochemistry’ also had to struggle with critique in the beginning, but are established labels now. Other terms like ‘cybernetics’ were controversially discussed and have never been fully embraced in academia.

ing through relabeling old ideas and without actually embracing new approaches. *Secondly, an area can simply fail for scientific reasons to realise the promises it made.*"

This second cause is linked to the hype-patterns of the R&D sphere when scientists in systems and synthetic biology articulate the fear that 'the bubble may burst'.²⁸ Over-hyping leads to the formulation of audacious promises concerning the scientific as well as technological potentials of new approaches. These promises include the kind of innovation, the time horizon of its realisation and its potential to solve societal problems. Currently, the need to formulate promises of all kinds to attract funding is perceived as still rising, whereas the failure to fulfil these promises is seldom sanctioned with direct measures. All actors involved seem to be well aware that scientific breakthroughs cannot be guaranteed for or predicted with precision. At the same time, there is a fair chance that money spent for scientific research will lead to *some* kind of innovation, be it in the form of new data, technologies, insights or applications.

**buzzwords, hype cycles
and 'bursting bubbles'**

Critique of buzzword-ism comes not as much from the public or from critical science studies (the latter in fear of 'jumping on the bandwagon' themselves, when contributing to the over-hyping of a field with their research on 'ethical, legal and social implications' of fields that do not really exist yet, cp. Nordmann 2007, Williams 2008), but from the scientific community. Scientists engaged in systems biology feel that they take the term very seriously and therefore invest a lot of effort in realising its claims (like a very elaborate interdisciplinary collaboration, the development of complex models, the production of sound and useful data, etc.) and thereby lose out on colleagues who use the term more lightly. Scientists who follow different research approaches and avoid using the new label fear to lose money and reputation for their own research approaches that are being hyped to a lesser degree. Both groups complain about a general decline of terminological precision and 'anything goes'-attitudes. Their critique can be seen as a struggle for limited resources as well as a defence of scientific and terminological soundness.

Use of language also has a cultural component and national context. Most of present day research labels have been launched in the USA,²⁹ including 'synthetic biology', 'systems biology', 'nanotechnology' and 'converging technologies' or funding slogans like 'Atoms for Peace', 'War against Cancer' or 'Human Enhancement'. This national contextualisation might not be as much of a bone of contention for scientists who perceive themselves already as global players and it is certainly not regarded as a disadvantage in the eyes of politicians who aim at 'narrowing a trans-continental innovation gap' and safeguarding national competitiveness by following the US example. Nevertheless, it does have some potential to raise public unease given a rather ambivalent opinion about US American culture and industry.

As for systems biology, the critique of buzzword-ism and the reluctance to make use of the new label seem to be significantly more pronounced among Austrian scientists than in other countries. With the available data, this situation becomes evident, but is difficult to explain. Some scientists refer to a rather conservative attitude within the Austrian research landscape that would also have led to a relatively late establishment of molecular biology some 30 years ago; others mention a lack of expertise in contributing fields like bioinformatics at the time when systems biology was introduced. One might also

²⁸ A formulation put forward by a British systems biology researcher (I 1).

²⁹ Although the first uses and definitions of these terms are sometimes of European origin.

explain the cautious attitude by more general effects of scale concerning both, the scale of the existing scientific community (and hence its ability to cover all specialities) and the scale of science funding (which was especially restricted during the period of interest). Hence, the establishment of national research networks, the funding of new, multidisciplinary centres and the participation in large EU funded projects are more challenging. The historical fact that one prominent forerunner of systems biology, Ludwig von Bertalanffy, stems from Austria and initiated the reading of a ‘theoretical biology’ at the University of Vienna already in the 1940ies does not really seem to affect this situation.³⁰

2.5 Why then investigate the establishment of a new research field?

The arguments made above all highlight the difficulty of investigating the establishment of a new research field. They also highlight the danger of contributing to science governance in a negative way, by ‘jumping on a bandwagon’ that is fuelled by a buzzword; a risk that is almost unavoidable as each use of a term conveys the message that the denoted field really existed and carried some relevance. Why, then, should one be interested at all?

General arguments for investigating the establishment of new research fields hold that

- an engagement with research fields early onwards in their development leave **more room for constructive interaction** between the dominant conception of the new research field, alternative standpoints, societal interests and R&D policies,
- **processes of R&D formation, institutionalisation and routinisation** are per se interesting subjects of investigation, allowing for further insights in the then prevalent general patterns and logics of change
- during transitional phases, general aspects of R&D become more evident and are voiced more explicitly by all actors involved than during more stable phases, hence allowing for **a better understanding of general patterns and logics at work in R&D**,
- in its early phase, the development of research fields seems to be influenced more strongly by their national contexts than later onwards when stable international research communities exist; investigating these early, to some extent formative phases, allows for **insights into the specificities of national innovation regimes**.

It has to be added here that all these promising goals are somewhat challenged by a lack of validated models of how innovation in science and technology really comes about. Societal ideas about such innovation seem to have gone through at least three paradigmatic stages, all of which still influence our current perception: a first stage where science and technology were really seen as *two distinct fields* and scientific research was more closely affiliated to scientific education than to technological application (illustrated by the Humboldtian university model); a second stage (with Vannevar Bush as its most prominent promoter) where science and technology were seen as *interlinked by a linear, unidirectional process*; and a third stage (sometimes associated with

divergent models of how innovation in science and technology really comes about

³⁰ Von Bertalanffy’s membership in the NSDAP cannot be left unmentioned here, although it is not widely known of and therefore is unlikely to have affected the recent take-up of his work (or lack thereof).

the term ‘technoscience’) where scientific and technological innovation are seen as so *closely interwoven* that any kind of funding will result in all kinds of innovation. All three models co-exist simultaneously today and shape current science and science policy discourse.³¹ Basic research, applied research and product development are sometimes distinguished (to argue for the autonomy of basic research, the public funding of applied research or the regulation of product development), sometimes they are depicted as causally related (to advertise the economic and societal benefits of basic research funding), sometimes they are conflated (for instance when promoting label-oriented funding initiatives or different levels of private-public partnership). Overall, the eclectic reference to one of the three models invokes the impression that scientific breakthroughs and technological innovation are linked by more or less simple cause-effect relations and hence can be predicted and planned for.

For systems biology research, the media as well as funding policy documents advertise the foreseeable production of revolutionary “new ideas, new tools and new data”, a radical change in our views “about how cells self-regulate, how life becomes more complex, how diseases develop and how evolution operates.” (ERASysBio 2007: 6) These are accredited with the potential to revolutionise the (bio)pharmaceutical sector, estimating “that cell-based systems biology in the USA could reduce drug discovery costs by € 330M and reduce development times by three years for each drug released to the market.” (ibid.: 13) Overall, systems biology is said to promise “enormous economic and social impact, probably comparable to that in the 20th century from advances in physics, which provided electrification, radio communication, electronics, telephony, internal combustion engines, atomic energy and the internet.” (ibid.: 15) Individual scientists support such hopes, promising a complete model of the brain in 10 years (ibid.: 16) or the completion of “a detailed and comprehensive simulation model of the human cell at an estimated error margin of 20 percent by the year 2020” and the identification “of the system profile for all genetic variations, drug responses, and environmental stimuli by the year 2030.” (Kitano, 2001: 25)

divergent claims about future breakthroughs

Scientists, when directly asked in interviews, point at the fact that they cannot really predict breakthroughs. They feel confident to predict incremental change to some extent and to envisage which new insight or technology could revolutionise their field of research. But *when* this new insight or technological innovation is going to be achieved, *by whom* and *by what means*, is mostly left open. Also, they admit that innovation might go into totally different, unforeseen directions and that predicted (epistemic or technological) revolutions might not happen at all. As for time spans, the interviewed scientists mention two different time horizons: one of about three to five years, equalling an average project length (or length of a PhD project); and one of about 20 years, which seems to refer to a time horizon that cannot really be overseen. Such uncertainties about the logics of innovation, its direction and time-scales persist among theoreticians of science as well as scientists and contribute to the problem of ‘bursting bubbles’ mentioned above. Their explication still helps to get a better grasp of innovation potentials in science and technology in the sense that prevalent uncertainties, ambiguities and gaps of evidence are addressed and specified. The hope is that their explicit description helps to take some steam out of the current over-hyping that is seen as detrimental by all interviewed scientists unequivocally.

³¹ The very idea that the three stages followed one after the other in history is contested by some experts as is the announcement of a technoscience era (cp. Forman 2007), their current parallel existence seldom is.

2.6 Investigating the establishment of a transnational research network from a national perspective

Scientific progress is commonly perceived to take place in a global sphere. The empirical investigation of systems biology in Austria also shows that international networks are far more important in the formation of research projects and in co-authorship selection than national networks. Still, the quality, speed and dimension of the establishment of systems biology in academia and industry differ considerably between the various national contexts. This situation is clearly linked to varying funding contexts and varying traditions of institutionalising science and research.

Moreover, the heterogeneity of systems biology approaches and its differentiation into schools seem to have a geographical component. The explanation of this pattern can draw upon the fact that epistemic approaches are sometimes developed in a very local context, closely linked to specific research laboratories and individual promoters of a specific approach; and it can also draw on the idea that – even though science is a transnational undertaking – a kind of national science culture exists.

The presented study opted for a national perspective, focusing on the Austrian context. Thanks to some additional research undertaken in the UK and the close collaboration with the German sub-project its results can also be compared to the British and the German context. Based on this national approach and the transnational comparison, it is possible to describe national specificities in more detail and to ask about their possible causes and consequences. Thereby, the close link between funding initiatives, institutional settings and the establishment of systems biology in Austria becomes more visible. Additionally, the specific challenges and opportunities an innovative, interdisciplinary and collaborative research approach faces in a small country with restricted resources can be highlighted. As noted by Marcus (2008), “the challenge is to find the ‘right-size’ science level for each problem”, somewhere between “the ‘small-science’ doctoral student looking at one DNA sequence to large international ‘big-science’ teams trying to develop computer models of multilevel physiological systems”. (ibid: 14)

3 Academic societies, research institutions, research groups and individual researchers dedicated to systems biology in Austria

3.1 Method of inquiry

This chapter presents an overview of academic societies, networks, institutions and individual researchers dedicated to systems biology in Austria (as of December 2011). Shortcomings of such an overview result from a difficulty to discern systems biology activities from non-systems biology activities (due to the heterogeneity of approaches and boundary drawings mentioned above) and a lack of quality, completeness, homogeneity and up-dating of web based data sources that formed the main bases of this investigation. Moreover, this survey does not necessarily allow conclusions concerning the importance of the individual institutions and researchers enlisted within the international systems biology community.

Systems biology networks, research institutions and researchers are enlisted based upon

- an *internet search* for systems biology research in Austria,
- a search for systems biology projects in the *databases of funding institutions*, namely the Vienna Science and Technology Fund (WWTF)³², the Austrian Science Fund (FWF)³³, and the Austrian Research Promotion Agency's (FFG) programme Genome Research in Austria (GEN-AU)³⁴
- a search for publications since 2000 with 'systems biology' in title, topic or keywords in the *Web of Science*³⁵.

The list of research actors also allows for drawing a map of systems biology research in Austria. The list of publications was further used for a co-authorship analysis. Furthermore, this report includes a list of the main funding institutions for systems biology research in Austria and gives an overview of how systems biology is embedded in the Austrian higher education system by enlisting past and current courses in systems biology.

In order to further categorise the prevalent research actors, three different categories were developed. These categories help to give an overview by indicating the individual actor's centrality within a national systems biology landscape. Here, again, we had to rely on the prominence of the label 'systems biology' in given profiles, combined with types of institutionalisation. For the full list of institutions and their descriptions, see chapters 6, 7 and 8.

³² Source: <http://www.wwtf.at/>, accessed June 12th, 2011.

³³ Source: <http://www.fwf.ac.at/index.asp>, accessed June 12th, 2011.

³⁴ Source: <http://www.gen-au.at/index.jsp?lang=de>, accessed June 12th, 2011. Unfortunately, the FFG does not provide a publicly accessible data bank storing information about all funded projects. Therefore, the search was restricted to the GEN-AU web site. Using its search option and the keywords 'systems biology' and 'Systembiologie', all projects resulting from this search were registered.

³⁵ Source: <http://wokinfo.com/>, accessed June 19th, 2011.

three categories of institutions

Category I includes all societies, networks and institutions with ‘systems biology’ in the title, in their main goal definition or/and the disciplinary affiliation of the director or head. The category is divided into academic societies & networks, institutions and research groups, depending on whether the whole institution/society/network or only one or more research groups work are dedicated to systems biology.

Characterisations presented for category I institutions in chapter 6 consist of following data (depending on data availability): a short profile (including type of institution, address, founding year, head, disciplinary profile, beginning of systems biology research and researchers involved in systems biology) and a more detailed account (delineating approach, staff, research groups, research projects, cooperation partners, teaching and publications).

Category II includes all academic societies, networks and institutions with ‘systems biology’ mentioned in projects or texts.

Characterisations presented for Category II institutions in chapter 7 offer (depending on data availability) short profiles and a short account (including all available information on staff, research groups, research projects, cooperation partners, teaching and publications).

Category III enlists all institutions that published one or more papers in the field of systems biology (‘systems biology’ in title and/or among keywords) and do research on the latter to an unknown degree.

Characterisations presented for Category III institutions in chapter 8 give the address, systems biology relevant experts, systems biology projects and systems biology publications published and researchers involved in systems biology. Sometimes, short descriptions are added.

3.2 Overview of systems biology in Austria

As noted above, the list of institutions and scientists dedicated to systems biology can be depicted geographically. This map provides a first overview of systems biology in Austria, including an attribution of institutions to categories I to III (Figure 5).

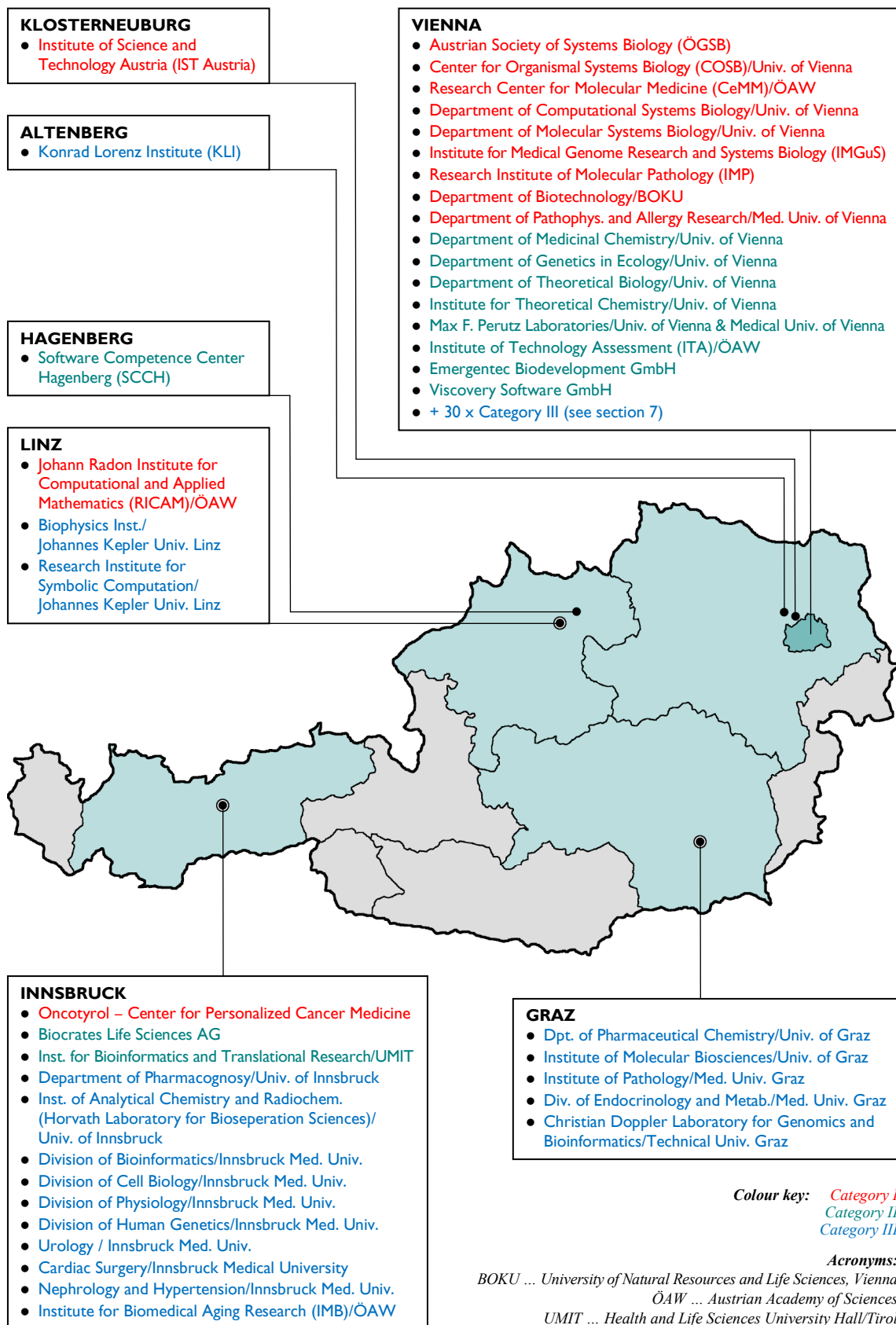


Figure 5: Map of systems biology research in Austria with attribution to categories I to III

3.3 **Disciplinary orientation and background of category I and II academic societies, networks and research institutions**

Systems biology research is by definition an interdisciplinary undertaking. All definitions of systems biology emphasise this central feature and highlight the importance of a symmetrical relationship between experimental and theoretical approaches. Mostly, this symmetrical relationship is depicted by iterative circles that link experimental and theoretical phases of research over time.

Nevertheless, systems biology research also takes place in given institutional contexts. This leads to specific research approaches and accounts to some extent for the heterogeneity of the current international systems biology landscape. In most cases in Austria, systems biology research is embedded in institutions with a more specific disciplinary or thematic focus. This may or may not result in systems biology research approaches that have a disciplinary or thematic focus point. To get an idea about the possible disciplinary focus points or strengths of Austrian systems biology research, an attempt was made to categorise institutions and scientists along disciplinary affiliations (Table 1). Again, such a categorization can only provide a tentative picture.

The categorisation of institutions follows their self-portraits.³⁶ Institutions are characterized along their affiliation to biomedicine, biology, bioinformatics & mathematics, chemistry and/or philosophy of science. The category ‘biology’ mostly relates to molecular biology, genetics and microbiology. Only in the cases of the Institute of Theoretical Biology and the Center of Organismal Systems Biology (COSB), both at the University of Vienna, ‘biology’ has a different scope, focusing on evolutionary and developmental biology and on the organismic level within zoology and human biology.

The categorisation of scientists is based upon their training, degrees and research, with an emphasis on PhD and habilitation topics. Data were retrieved from curricula vitae available on the Internet. Scientists are characterised along their affiliation to biomedicine, clinical medicine, biology, bioinformatics, mathematics, physics, chemistry and/or science & technology studies.

institutional focus on biomedicine and biology

The clustering of institutes with similar disciplinary foci in Table 1 (left side) shows a relative dominance of institutes with a primary focus on biomedicine or (molecular or micro-) biology. Only a handful of institutions with systems biology research groups feature a primary focus on bioinformatics & mathematics (most notably: RICAM) or on chemistry (most notably: the Institute for Theoretical Chemistry). A dual focus on biomedicine AND bioinformatics & mathematics or on biology AND bioinformatics & mathematics is rare at the institutional level, although examples exist (Oncotyrol, Dpt. of Computational Systems Biology, IST Austria).

³⁶ The Institute of Technology Assessment (ÖAW) and the Department of Theoretical Biology (Univ. of Vienna) were not included in this analysis, because these institutions concentrate on meta-level questions relating to systems biology. Therefore, their contribution to systems biology research is of a different kind. Still, Manfred Drack from the Department of Theoretical Biology is mentioned as a researcher embedded in COSB, as the Department of Theoretical Biology is a member of COSB and his publications are currently the only COSB-affiliated publications explicitly addressing systems biology.

A dual focus bridging *in silico* and *in vitro* research is nevertheless present within Austrian systems biology research. This becomes more evident when depicting the (sub-)disciplinary affiliations of individual scientists (Table 1, right side). At this level, physics and chemistry are much more present and bioinformatics and mathematics are slightly more present.

**bridging the *in silico*
– *in vitro* *in vivo* gap**

The extent to which *in silico* and *in vitro* (or *in vivo*) research are combined within research could be further delineated when including (sub-)disciplinary affiliations at an organisational level below the one chosen here (divisions, departments, research groups). One could also include all members of a research group additionally to their principal investigators and give more credit to multi-disciplinary careers of individual researchers, thereby featuring *all* (sub-) disciplinary resources available within the research process. These two aspects are not presented here, to the effect that it is only the (probable) *primary* disciplinary focus and not the overall interdisciplinary width that is depicted.

Table 1: Primary disciplinary affiliations for category I and II research institutions (in alphabetical order, secondary affiliations hatched) and systems biology researchers

Institution	Disciplines					Systems Biology Researcher	Disciplines							
	Biomedicine	Biology	Bioinformatics & Mathematics	Chemistry	Philosophy of Science		Biomedicine	Clinical Medicine	Biology	Bioinformatics	Mathematics	Physics	Chemistry	Philosophy of Science
CeMM (Research Center for Molecular Medicine)/ÖAW						Superti-Furga, G.								
Institute of Pathology/ Medical University Graz						Zatloukal, K.								
Dpt. of Pathophysiology and Allergy Research/MUW						Mechtcheriakova, D.								
Oncotyrol – Center for Personalized Cancer Medicine						Graber, A.								
Biocrates Life Sciences AG						Deigner, H.-P.								
						Enot, D. P.								
						Koal, T.								
						Osprian, I.								
						Weinberger, K.								
Institute for Medical Genome Research and Systems Biology (IMGuS)						Zacherl, N.								
Dpt. of Biotechnology/BOKU						Grabherr, R.								
						Kreil, D. P.								
Dpt. of Molecular Systems Biology/Univ. of Vienna						Weckwerth, W.								
						Wienkoop, S.								

Institution	Disciplines					Systems Biology Researcher	Disciplines							
	Biomedicine	Biology	Bioinformatics & Mathematics	Chemistry	Philosophy of Science		Biomedicine	Clinical Medicine	Biology	Bioinformatics	Mathematics	Physics	Chemistry	Philosophy of Science
Dpt. of Genetics in Ecology/Univ. of Vienna						Schleper, C.								
Max F. Perutz Laboratories						Hirt, H.								
						Kuchler, K.								
Research Institute of Molecular Pathology (IMP)						Mechtler, K.								
						Stark, A.								
Emergentec Biodevelopment GmbH						Mayer, B.								
						Mühlberger, I.								
						Perco, P.								
						Wiesinger, M.								
Center for Organismal Systems Biology (COSB)						Drack, M.								
Dpt. of Computational Systems Biology/Univ. of Vienna						Rattei, T.								
						Widder, S.								
The Institute of Science and Technology Austria (IST Austria)						Bollenbach, T.								
						Guert, C.								
						Henzinger, T.								
Johann Radon Institute for Computational and Applied Mathematics (RICAM)/ÖAW						Engl, H. W.								
						Kugler, P.								
						Lu, J.								
						Schmeiser, C.								
Institute for Bioinformatics and Translational Research/UMIT						Graber, A.								
						Dehmer, M.								
Institute for Theoretical Chemistry/Univ. of Vienna						Flamm, C.								
						Hofacker, I. L.								
						Schuster, P.								
Dpt. of Medicinal Chemistry/Univ. of Vienna						Noe, C.								

3.4 The geography of Austrian systems biologists

Besides their disciplinary and institutional affiliation, one can also ask about the past national affiliations of systems biologists currently working in Austria. Such an analysis of the ‘geographic past’ of key players within Austrian systems biology allows for a more detailed analysis of the current state of globalisation within this community.

Searching through data on individual career tracks available on the internet, three different data sets were prepared (as of March 20th, 2012):

- the country in which systems biologists currently active in Austria completed their PhD
- the country they stayed in before moving to Austria
- the length of time they have already spent in Austria without cease until now.

Again, the reliability of these data is limited by the reliability of the on-line data sources and, in a few cases, the attribution to a specific category was not unequivocal. Still, the overall results are likely to be fairly robust.

Of 31 systems biologists currently working in Austria (of the 40 systems biologists identified earlier onwards, those nine that work in companies were ignored because their national affiliations were difficult to ascertain and their influence on the academic field is likely to be less strong), 58 % completed their PhD in Austria. Another 23 % completed their PhD in Germany; 10 % in the US and 3 % (i.e., one person) each in the UK, Russia and Switzerland (Figure 6).

**the international
provenance of systems
biology researchers**

PhD completed in ...

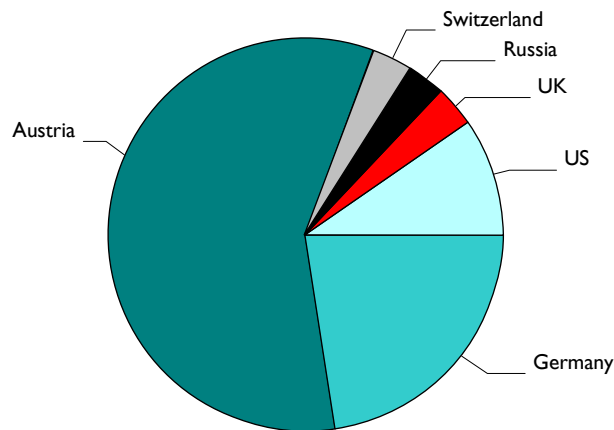


Figure 6: Country in which the PhD was completed

Of these same 31 scientists, 49 % held their last position in Austria, while 26 % moved to Austria from Germany, 13 % from the US and 3 % (one person) each from the UK, Switzerland, Spain and Norway (Figure 7).

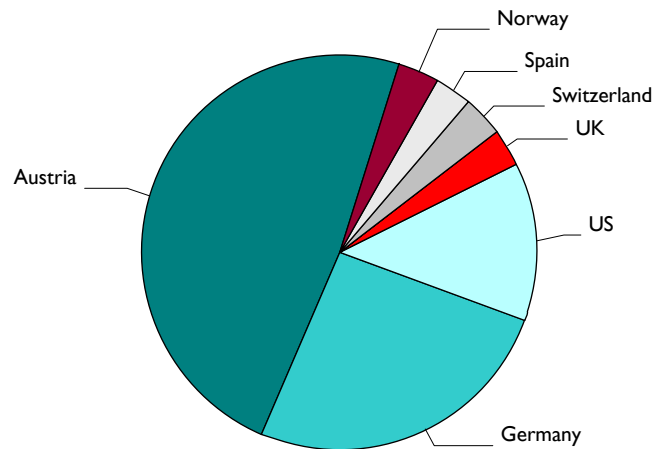
Last position (since 2000) held in ...

Figure 7: Country in which the last position was held taking into account the past 12 years.

**geographical flexibility
of systems biology
researchers**

As for the length of time these 31 scientists have been staying in Austria without major interruptions, 26 % only have moved to Austria in or after 2009; 26 % have moved to Austria in or after 2000; and 35 % have been staying in Austria at least for the past twenty years (Figure 8).

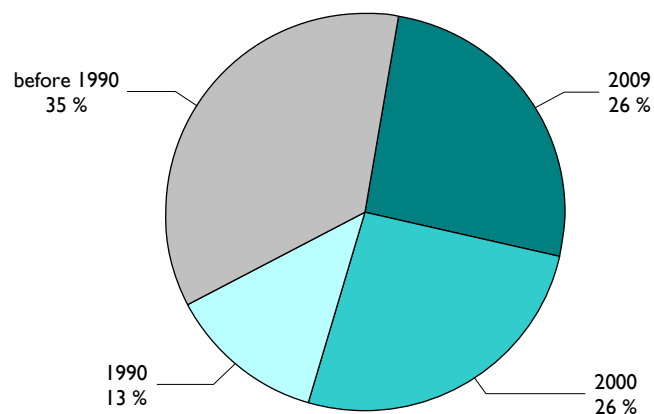
In Austria since ...

Figure 8: Length of time spent in Austria without interruption before 2011

Overall, these results show that of 31 academic systems biology researchers currently working in Austria, around three quarters have spent most of their scientific career in Austria or Germany, the only other geographic context more than one scientists stems from being the US. Some scientists moved to Germany or the US (or Spain or Norway) for a longer time period³⁷ after completing their PhD in Austria and returned back to Austria afterwards.

³⁷ Stays shorter than one year were not taken into account.

Moreover, one quarter of the 31 systems biologists currently active in Austria has only moved to Austria during the past years, when systems biology already represented an internationally recognized focus of life science research. Another quarter has moved to Austria between 2000 and 2009, a phase of establishment of systems biology in the international context and of a generational turn-over at Austrian universities. Another one third has been staying in Austria all along, showing a geographical stability not atypical for earlier generations of scientists but less common nowadays.³⁸

3.5 Timeline of systems biology in Austria

Besides the ‘early school of systems biology’ in Vienna, represented by the scientists Hans Leo Przibram, Paul A. Weiss and Ludwig von Bertalanffy (Drack et al. 2007) and situated at the ‘Biologische Versuchsanstalt’ in the Viennese Prater (1902–1947) as well as at the University of Vienna (until Bertalanffy’s suspension in 1945 and his permanent leave in 1947), current ‘new’ systems biology research centres, institutes, departments, groups and companies have not been established before 2000 (see Figure 9). The Research Center for Molecular Medicine (CeMM) at the Austrian Academy of Sciences is one of the first of such foundations; it represents until now the only big research centre dedicated to systems biology and situated in its own building (officially opened in 2010) in Austria. The establishment of CeMM was followed by the creation of an Austrian Society of Systems Biology and of two small, systems biology affiliated companies, Biocrates Life Sciences AG and Emergentec Biodevelopment GmbH around 2002. A major milestone regarding broader capacity building for systems biology research in Austria was set in 2003 with the start of the Bioinformatics Integration Network and the Austrian Proteomics Platform funded by the GEN-AU programme of the FFG.

**‘old’ and ‘new’
systems biology**

In the following years, a few individual research groups strengthened their focus on systems biology or were newly established with an explicit focus on systems biology. This includes research groups at the department of biotechnology at the BOKU, at the departments of medicinal chemistry and of theoretical biology as well as at the institute for theoretical chemistry at the University of Vienna, at the department of pathophysiology and allergy research at the Medical University of Vienna, at the Institute of Molecular Pathology (IMP), at the newly established RICAM of the Austrian Academy of Sciences, at the newly established Max F. Perutz Laboratories, at the newly established Center for Personalised Cancer Medicine (Oncotyrol), at the newly established institute for bioinformatics and translational research at the UMIT, at the Software Competence Center Hagenberg (SCCH) and at the newly established IST Austria.

The long envisioned Institute of Medical Genome Research and Systems Biology (IMGuS) came to life around 2006 in the form of a coordinatory platform for two systems biology research projects. Around 2009, another company, Viscovery Software GmbH, started contributing to a systems biology project. And in 2009 and 2010, two new institutes dedicated explicitly to molecular and computational systems biology opened their doors at the University of Vienna.

³⁸ A methodical investigation of such more general patterns would allow for a better validation of this conclusion we mostly derived from expert interviews. Unfortunately, it is currently not available for the Austrian context.

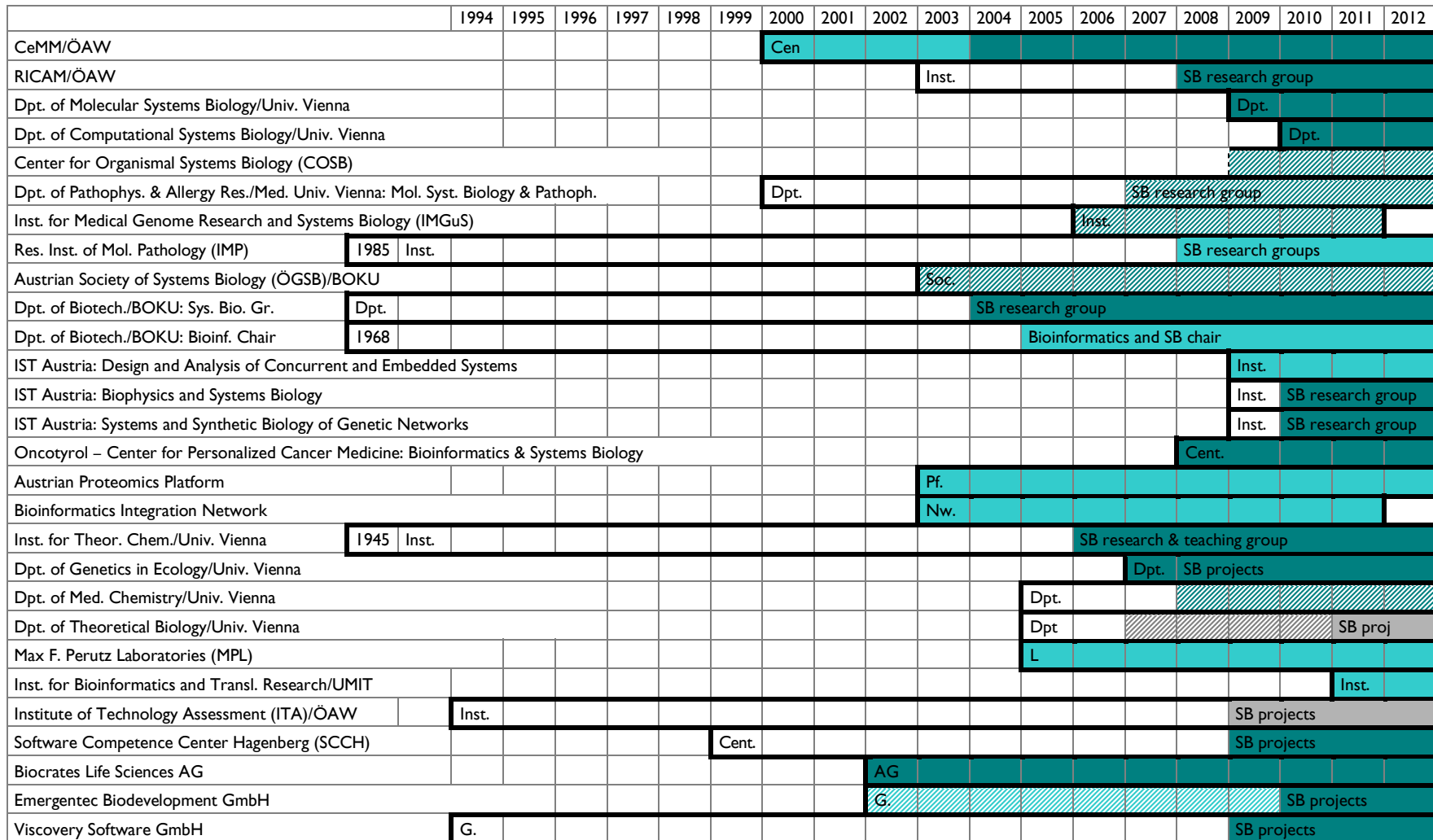


Figure 9: Beginning of systems biology focus at Austrian universities, extra-university research institutes and companies. Dark green colouring: explicit systems biology focus (hatched: unclear level of activity); light green colouring: systems biology relevant activities; grey colouring: philosophy and sociology of science activities; dark frames indicate the establishment of the entity the systems biology activities are situated at (centres, institutes, departments, platforms, networks and companies)

3.6 Co-authorship networks of Austrian and international systems biology researchers

The analysis of co-authorship networks allows for delineating scientific collaboration among researchers.³⁹ Thereby, it is important to keep in mind that a cluster of connected authors doesn't necessarily mean that they represent a coherent group. For example, author A co-authored a paper with author B and another paper with author C. Although authors B and C are connected by author A, authors A, B and C do not necessarily represent a coherent group or school.

To get a first impression, two small scale co-authorship analyses of Austrian systems biology researchers and international systems biology researchers were conducted.

Austrian systems biology researchers were selected by the criteria of being part of an institution of Category I or II, and having publications since 2000 with 'systems biology' in title, topic or keywords (based on Web of Science database⁴⁰). This led to a result of 40 'Austrian' systems biology researchers (for a list and full names see annex). 'Austrian' is thereby defined as 'based at an Austrian institution in the year 2011'. It has to be noted here, that many of these scientists have moved to an Austrian research institute only a few years ago.⁴¹ All publications by these 40 authors since 2000 were included in the network analysis.

International systems biology researchers were selected by the criterion of having publications with 'systems biology' in title, topic or keywords in the Web of Science database since 2000 (7092 publications match this characteristic). The 100 authors with the highest number of systems biology publications were then selected (based upon the Web of Science list, corrected for inconsistencies). See annex for a full list.

The network analyses were performed with the programme Pajek⁴² and resulted in two co-authorship networks:

1. Co-authorship network of 40 Austrian systems biology researchers (all publications since 2000 in Web of Science)
2. Co-authorship network of Top-100 systems biology researchers and Austrian systems biology researchers (systems biology publications since 2000 in Web of Science)

All visualisations depict authors as nodes and co-authored papers as lines (with distance, thickness of lines and/or values indicating the number of papers).

³⁹ Due to restricted resources, a more detailed analysis, including co-citation analyses, could not be performed within this project.

⁴⁰ <http://apps.webofknowledge.com/>, accessed Sept. 14th, 2011.

⁴¹ In addition to the high geographical mobility of scientists, Austrian universities face somewhat of a generation change at the moment, with many (Austrian) professors retiring at the same time and their positions being filled with new (international) candidates or being transformed into new chairs which are then also filled with new (international) candidates. The former mode of 'Hausberufung' (filling a position with a candidate stemming from the same institution and hence also the same country) is thereby abandoned. Due to language constraints, most of the international candidates stem from Germany. A more detailed analysis and reliable description of this observable generation change would necessitate a methodological investigation.

⁴² Source: V. Batagelj, A. Mrvar: Pajek – Program for Large Network Analysis, <http://vlado.fmf.uni-lj.si/pub/networks/pajek/>, accessed Sept. 14th, 2011.

3.6.1 Co-authorship network of Austrian systems biologists

In Figure 10, the co-authorship network of Austrian systems biology researchers is arranged in a circle. Small circles indicate authors belonging to the same institution; circle colours indicate the main disciplinary focus of this institution.

**intra- and inter-
institutional, intra- and
interdisciplinary
co-authorship networks**

Co-authorship is realised preferably within a single institution, whereas *inter*-institutional collaboration seems to be more common in medical fields. Very little co-authoring takes place in the areas of biology, physics/chemistry, bioinformatics and technology assessment. Interdisciplinary co-authoring occurs between medicine and biology, biology and bioinformatics, and bioinformatics and physics/chemistry.

3.6.2 Co-authorship networks of Austrian systems biologists and top-100 international systems biologists

Figure 11 depicts a co-authorship network for the top-100 international systems biology researchers (most papers with ‘systems biology’ in title, topic or keywords) and all Austria-based systems biologists. Top-100 systems biology authors are represented by red nodes (among them Wolfram Weckwerth as the only Austrian representative), all other Austrian systems biologists are represented by blue nodes. Only publications with ‘systems biology’ in title, topic or keywords are considered for co-authorship links.

The network is visualized based upon automatic layout generation (algorithm Kamada-Kawai in Pajek); components were optimized separately (a few manual adjustments enhance visibility of nodes and edges). Authors who did not co-author papers with the top-100 international systems biology researchers are listed on the right side of Figure 9.

**national and
international
co-authorship networks**

Besides the international network, there are two separate conceivable Austrian networks: the Biocrates Life Sciences AG (Koal, Deigner, Enot) and a second cluster consisting of the Institute for Theoretical Chemistry at the University of Vienna (Schuster, Flamm), the Johann Radon Institute for Computational and Applied Mathematics at the Austrian Academy of Sciences (Engl, Kügler, Lu) and the Department of Computational Systems Biology at the University of Vienna (Widder).

The authors Noe (Department of Medicinal Chemistry, University of Vienna), Schleper (Department of Genetics in Ecology, University of Vienna) and Drack (Department of Theoretical Biology, University of Vienna) are linked to the international systems biology network via individual publications with Westerhoff. Wienkoop and Weckwerth (Department of Molecular Systems Biology, University of Vienna) show even stronger links to the international network. Graber co-authored papers with Westerhoff and Holmes and therefore links the Institute for Bioinformatics and Translational Research to the big network component. This institute is also linked to the Biocrates Life Sciences AG (Osprian, Weinberger) and Emergentec Biodevelopment GmbH (Mayer, Perco, Wiesinger, Mühlberger). Superti-Furga (CeMM, Austrian Academy of Sciences) shows the strongest co-authorship activity with international systems biologists.



Overall, Austrian scientists do not publish extensively under the label of ‘systems biology’. Austrian systems biologists seem to either concentrate on collaborating with other Austrian systems biologists or to concentrate on collaborating with systems biologists based in other countries (Graber, Wienkoop and Weckwerth being the only authors with national as well as international systems biology co-authorships). The general level of Austrian systems biologists’ international integration is rather low. Moreover, networking between Austrian systems biology research groups is still scarce – presumably in its beginnings.⁴³

⁴³ Recent networking activities like the ‘Workshop at the Interface of {Molecular Biology U Medicine} and {Computational U Applied Mathematics}’ organised jointly by RICAM and CeMM on February 16th, 2012 point at a possibly stronger trans-institutional integration in the near future.

4 University courses in systems biology

In order to get an overview of how systems biology is embedded in Austrian university curricula, all online university teaching databases were searched for lectures with ‘systems biology’ or ‘Systembiologie’ in their title (as of June 6th, 2011). The results were summarized in historical order.⁴⁴ Additionally, all universities of applied sciences’ (‘Fachhochschulen’) databases were searched for courses featuring ‘systems biology’ or ‘Systembiologie’ in their title (as of October 1st, 2011). For these, only the current curricula are taken into account (due to a lack of data about previous courses).

In total, 18 courses targeting ‘systems biology’ or ‘Systembiologie’ were found, with the first course starting in 2004 (see Table 2). The results show that most of the courses are being or have been held at the University Vienna (ten courses), followed by the Technical University of Graz (two courses) and the University of Natural Resources and Life Sciences (Universität für Bodenkultur, BOKU), the Health and Life Sciences University (Private Universität für Gesundheitswissenschaften, medizinische Informatik und Technik, Hall in Tirol, UMIT), the University of Salzburg and the FH Joanneum – University of Applied Sciences, the FH Campus Vienna – University of Applied Sciences and the FH Hagenberg – University of Applied Sciences Upper Austria with one course each. This leaves many research institutions that are doing systems biology research without any teaching addressing this topic as a major theme, although the total number of courses has been increasing during the last years. Furthermore, courses in systems biology are not held each semester at each site. They are predominantly held as lectures, with only a few interactive seminars and hands-on practical courses.

***marginal role of systems
biology in university
curricula***

Systems biology courses include:

- Grundlagen der Systembiologie [Fundamentals of systems biology] (Univ. of Vienna, Institute for Theoretical Chemistry)
- Aktuelle Technologien in der Systembiologie [Current technologies in systems biology] (Univ. of Vienna, Center for Molecular Biology, Dpt. for Biochemistry and Cellbiology)
- Einführung in die Anwendung der Systembiologie in den pharmazeutischen Wissenschaften [Introduction into the application of systems biology in the pharmaceutical sciences] (University of Vienna, external lecturer in pharmacy)
- Evolution und Systembiologie [Evolution and systems biology] (University of Vienna, external lecturer in pharmacy)
- Bioinformatik und Systembiologie [Bioinformatics and systems biology] (University of Vienna, Dpt. of Computational Systems Biology)
- Grundlagenpraktikum Systembiologie [Practical course in systems biology] (Univ. of Vienna, Dpt. of Computational Systems Biology)
- Current Topics in Computational and Systems Biology – Literature seminar (University of Vienna, Dpt. of Computational Systems Biology)
- Ausgewählte Kapitel aus Biomathematik/Mathematische Methoden der Systembiologie [Selected chapters from biomathematics/mathematical methods in systems biology] (Univ. of Vienna, Institute of Mathematics)

⁴⁴ Not all on-line databases go back to the same year; therefore the information provided for courses in distant years is incomplete to varying degrees.

- Plant Metabolism – Plant Systems Biology: modern methods in Systems Biology, metabolomics, proteomics (University of Vienna, Dpt. of Molecular Systems Biology)
- Analytical Methods in Systems Biology (University of Vienna, Dpt. of Molecular Systems Biology)
- Systembiologie [Systems biology] (BOKU, Institute of Applied Microbiology)
- Systembiologie [Systems biology] (TU Graz, Institute of Molecular Biotechnology)
- Formal Methods for Systems and Synthetic Biology (TU Graz, Signal Processing and Speech Communication Lab)
- Systembiologie [Systems biology] (UMIT)
- Systems Biology of Human Diseases (Univ. of Salzburg, Dpt. of Cell Biology)
- Einführung in die Systembiologie [Introduction to systems biology] (FH Joanneum – University of Applied Sciences)
- Systembiologie [Systems biology] (FH Campus Vienna – University of Applied Sciences)
- Ausgewählte Kapitel der Systembiologie [Selected chapters of systems biology] (FH Hagenberg – Univ. of Applied Sciences Upper Austria).

Whether systems biology represents a constitutive part of lectures and seminars with a broader thematic scope (not mentioning it in the title), is more difficult to assess. A few unsystematic conversations with students do not hint into such a direction; rather, explicit reference to systems biology seems to be restricted to a few courses.

Also, systems biology seems to elicit much lower interest among students than, for instance, at some British or German universities with established systems biology curricula. This lack of enthusiasm resonates with the dominant (critical) opinion among university teachers, a scattered teaching programme and a lack of visible career opportunities in Austria. Whole curricula, PhD or master programmes in systems biology do not exist in Austria at the moment.

At the extra-curricular level, it is noteworthy to mention the biannual, international FEBS (Federation of the European Biochemical Societies) “Advanced Lecture Course on Systems Biology”. It was first held in 2005 in Gosau (Upper Austria), then again in 2007, 2009 (in Alpbach, Tyrol) and 2011 (in Innsbruck, Tyrol). It is steered by Hans Westerhoff (The Netherlands, UK), Karl Kuchler (AT), Edda Klipp and Ursula Kummer (DE), Frank Bruggeman and Anneke Koster (NL), Uwe Sauer (CH) and Jacky Snoep (RSA).

The situation of higher education in systems biology in Austria also has to be assessed against a broader (although not very fiercely held) international debate about how systems biology can and should be taught. Especially, *at which point* systems biology teaching should set in during higher education curricula (at pre-graduate, post-graduate, PhD or masters level), and *how* it should introduce interdisciplinarity (teaching each required discipline additively or teaching transdisciplinary contents and skills). With new generations of scientists, systems biology could either become a (trans)discipline in its own right or stay an inter- or even multi-discipline that builds upon previous, (sub-)disciplinary specialisations.

Table 2: Systems biology courses at Austrian universities (including 'Fachhochschulen'). Courses are ordered along universities and these according to the first introduction of such courses. Lectures are coloured in green, practical courses and seminars in pink.

Course title	Institution	Curriculum	Lecturers	ECTS	Type	SS 04	WS 04/05	SS 05	WS 05/06	SS 06	WS 06/07	SS 07	WS 07/08	SS 08	WS 08/09	SS 09	WS 09/10	SS 10	WS 10/11	SS 11	WS 11/12	SS 12
Systembiologie	BOKU	Biotechnology	Grabherr, Rüker, Bayer, Striedner	3	VO	X		X		X		X		X		X		X				X
Aktuelle Technologien in der Systembiologie	Univ. of Vienna	Molecular Biology	Schüller, Köcher	2	VO		X		X		X		X		X		X					
Grundlagen der Systembiologie	Univ. of Vienna	Molecular Biology	Flamm	3	VO						X		X		X		X		X		X	
Einführung in die Anwendung der Systembiologie in den pharmazeutischen Wissenschaften	Univ. of Vienna	Pharmacy	Aszódi	(2)	VO					X												
Evolution und Systembiologie	Univ. of Vienna	Pharmacy	Aszódi	2	VO							X										
Bioinformatik und Systembiologie	Univ. of Vienna	Computer Science	Aszódi; Rattei since WS 10	3	VU								X		X		X		X		X	
Ausgewählte Kapitel aus Biomathematik (Mathematische Methoden der Systembiologie)	Univ. of Vienna	Mathematics	Hofbauer	5	VO									X								
Analytical Methods in Systems Biology	Univ. of Vienna	Biology	Weckwerth, Tanaka	1	VO											X						
Plant Metabolism – Plant systems biology: modern methods in systems biology, metabolomics, proteomics	Univ. of Vienna	Biology	Weckwerth, Wienkoop, Hadacek	3	VO													X		X		X
Grundlagenpraktikum Systembiologie	Univ. of Vienna	Biology	Widder, Ekker	5	SE															X		X
Current Topics in Computational and Systems Biology – Literature seminar	Univ. of Vienna	Biology	Widder, Rattei	2	SE															X		X
Introduction in the Evolutionary Systems Biology – What do 'Big-Data-Approaches' add to our understanding of systems?	Univ. of Vienna	Biology	Pavlicev	3	VO																	X
Systems Biology of Human Diseases	Univ. of Salzburg	Molecular Biology	Mewes	2	VO							X		X		X		X		X		X

Course title	Institution	Curriculum	Lecturers	ECTS	Type	SS 04	WS 04/05	SS 05	WS 05/06	SS 06	WS 06/07	SS 07	WS 07/08	SS 08	WS 08/09	SS 09	WS 09/10	SS 10	WS 10/11	SS 11	WS 11/12	SS 12
Systembiologie	TU Graz	Botanics, Biotechnology	Blank, Glieder, Schneideler, Hartner	(5)	VO									X		X		X		X		X
Formal Methods for Systems and Synthetic Biology	TU Graz	n/a	Köppl	(3)	VO											X		X		X		?
Systembiologie	UMIT	n/a	Baumgartner	n/a	VO												X					
Einführung in die Systembiologie	FH Joanneum	Applied Bioanalytical Sciences	n/a	2	VO																X	
Systembiologie	FH Campus Vienna	Molecular Biotechnology (Master)	n/a	1	VO																X	
Ausgewählte Kapitel der Systembiologie	FH Hagenberg	Biomedical Informatics (Master)	n/a	5	UE+VO																	X

5 Category I institutions

For each institution, short descriptions and profiles are presented. Uncertain data are indicated by an asterisk (*). Source of information is the official website of the institution unless otherwise stated.

The category ‘systems biology projects’ mentions projects funded within the 6th and 7th Framework Programme of the EU⁴⁵, within the two European ERANET funding initiatives ERASysBio⁴⁶ and SysMO⁴⁷, within the national GEN-AU funding initiative of the FFG⁴⁸ or by the national funding agency FWF⁴⁹.

The category ‘systems biology publications’ refers to publications published between 1/2000 and 7/2011 with ‘systems biology’ in title, topic or keywords found in Web of Science⁵⁰.

5.1 Academic societies & networks

5.1.1 Austrian Society of Systems Biology (ÖGSB)

Short description⁵¹: Reingard Grabherr is chairwoman of the society since 2003, which is also assumed to be its founding year. Another member of the ÖGSB is Wolfgang Ernst⁵².

Address: n/a

Website: n/a

Founded: 2003*

Systems biology since: 2003*

Chairwoman: Reingard Grabherr

Further members: Wolfgang Ernst

Type: academic society

Disciplinary profile: n/a (food science and biotechnology)

Systems biology projects: n/a

Courses in systems biology: n/a

Systems biology publications: n/a

⁴⁵ <http://cordis.europa.eu/search/index.cfm?fuseaction=proj.advSearch>, accessed March 13th, 2012.

⁴⁶ <http://www.erasysbio.net/index.php?index=311>, accessed March 5th, 2012.

⁴⁷ <http://www.sysmo.net/>, accessed April 2nd, 2012.

⁴⁸ As mentioned earlier, the FFG unfortunately does not provide a publicly accessible databank storing information about all funded projects. Therefore, the search was restricted to the GEN-AU web site. Using its search option and the keywords ‘systems biology’ and ‘Systembiologie’, all projects resulting from this search were registered.

⁴⁹ <http://www.fwf.ac.at/index.asp>, accessed June 12th, 2011.

⁵⁰ <http://apps.webofknowledge.com/>, accessed July 19th, 2011.

⁵¹ https://forschung.boku.ac.at/fis/suchen.person_uebersicht?sprache_in=de&menue_id_in=101&id_in=4804, accessed June 25th, 2011.

⁵² Source: <http://www.systemsbiology.at/team/show/id/15>, accessed June 30th, 2011.

5.1.2 Center for Organismal Systems Biology (COSB)/ University of Vienna

Short description: “The center unites eight departments devoted to research in organismal biology through the shared interest in understanding organisms as complex systems. This common scientific goal is approached through the integrated study of temporal and structural organization, of the dynamics of physiological, developmental, and evolutionary processes, and of the neuronal, mental, social, and environmental information flows in organismal systems.”

The foundation of COSB can be seen as an effect of a university reform that was realised around 2005 and encouraged the establishment of multi-departmental centres and as a reaction to the establishment of two new chairs under the labels of ‘molecular systems biology’ and ‘computational systems biology’ at the same campus (i.e., the ‘Biozentrum Althanstraße’).

Address: A-1090 Vienna

Website: <http://www.univie.ac.at/Lebenswissenschaften/OrgSysBiol/osbiol.html>

Founded: 2009*

Systems biology since: n/a

Speaker: Gerd B. Müller, Department of Theoretical Biology

Members: Dpt. of Anthropology, Dpt. of Behavioural Biology, Dpt. of Cognition Research, Dpt. of Evolutionary Biology, Dpt. of Integrative Zoology, Dpt. of Molecular Evolution and Development, Dpt. of Neurobiology, Dpt. of Theoretical Biology

Type: association of eight university departments

Disciplinary profile: diverse (organismal biology)

Systems biology projects: n/a

Courses in systems biology: n/a

Systems biology publications: n/a

5.2 Research institutions (centers, departments, institutes, companies)

5.2.1 Research Center for Molecular Medicine (CeMM)/ Austrian Academy of Sciences

Short description⁵³: The Research Center for Molecular Medicine GmbH (CeMM) of the Austrian Academy of Sciences is a research institution in the area of molecular medicine (cancer, inflammation, immune disorders), chemical biology and bioinformatics. Founded in 2000 – which is also the estimated start of systems biology research – it has about 109 scientific staff members, working in 10 laboratories. Since 2005, Giulio Superti-Furga functions as scientific director.

Address: Lazarettgasse 14, AKH BT 25.3, A-1090 Vienna

⁵³ Source of information is the official website of the institution, unless otherwise stated: http://de.wikipedia.org/wiki/Forschungszentrum_f%C3%BCr_Molekulare_Medizin, accessed July 22nd, 2011.

Website: <http://www.cemm.oeaw.ac.at/>

Founded: 2000

Systems biology since: 2000*

Head: Giulio Superti-Furga

Other systems biology researchers: Denise P. Barlow, Andreas Bergthaler, Christoph J. Binder, Kaan Boztug, Sylvia Knapp, Robert Kralovics, Sebastian Nijman, Joanna Loizou, Thijn Brummelkamp, Keiryn L. Bennett, Jacques Colinge, Stefan Kubicek

Type: research centre of the Austrian Academy of Sciences, GmbH

Disciplinary profile: (systems biology): molecular medicine, chemical biology, bioinformatics

Courses in systems biology: n/a

Systems biology projects:

I-FIVE (FP7-IDEAS)

ASSET (FP7-HEALTH)

Austrian Proteomics Platform II (FFG)

Austrian Proteomics Platform III (FFG)

Systems biology publications: 3

Superti-Furga, G., 2005, Proteomics, systems biology and molecular medicine, Febs Journal 272, 433-434.

Rix, U. and Superti-Furga, G., 2009, Target profiling of small molecules by chemical proteomics, Nature Chemical Biology 5(9), 616-624.

Kocher, T. and Superti-Furga, G., 2007, Mass spectrometry-based functional proteomics: from molecular machines to protein networks, Nature Methods 4(10), 807-815.

5.2.2 Department of Computational Systems Biology/ University Vienna

Short description⁵⁴: The Department of Computational Systems Biology at the University of Vienna was founded in spring 2010⁵⁵. Currently, the department has six staff members – with Thomas Rattei (Head) and Stefanie Widder as key systems biology researchers.

Address: Althanstraße 14, A-1090 Vienna

Website: <http://compsysbio.univie.ac.at/>

Founded: Spring 2010

Systems biology since: Spring 2010

Head: Thomas Rattei

Other systems biology researchers: Stefanie Widder

Type: university department – research & education

Disciplinary profile (systems biology): (genome-orientated) bioinformatics, genomics

⁵⁴ Source of information is the official website of the institution given below, unless otherwise stated.

⁵⁵ Source: http://ecology.univie.ac.at/fce-news/einzelansicht/article/departement-opening-on-june-25th-2010-department-of-computational-systems-biology/?tx_ttnews%5BbackPid%5D=69894&cHash=557024b846e044440c26694902b8cb03, accessed June 20th, 2011.

Systems biology research projects: n/a

Courses in systems biology⁵⁶:

SE Grundlagenpraktikum Systembiologie (English: practical course on systems biology), 5 ECTS (3h)

SE Current Topics in Computational and systems biology – Literature seminar, 2 ECTS, (2h)

VU Bioinformatik und Systembiologie (English: Bioinformatics and systems biology), 3 ECTS (2h)

Systems biology publications: 0

5.2.3 Department of Molecular Systems Biology (MoSys)/ University Vienna

Short description: The Department of Molecular Systems Biology was founded in 2009. Main systems biology researchers are Wolfram Weckwerth, Stefanie Wienkoop, Markus Teige and Volker Egelhofer.

Address: Althanstraße 14, A-1090 Vienna

Website: <http://www.univie.ac.at/mosys/>

Founded: 2009

Systems biology since: 2009

Head: Wolfram Weckwerth

Other systems biology researchers: Stefanie Wienkoop, Markus Teige, Volker Egelhofer

Type: university department – research, education

Disciplinary profile (systems biology): molecular plant physiology

Systems biology research projects:

EPISYSBIOL (FP7-PEOPLE)

‘Leguminosen: Multilevelanalyse hin zur Trockenresistenz’ (FWF Eintelprojekt), PathoNet – Das Pflanzenimmunsystem’ (FFG, GEN-AU)

Courses in systems biology⁵⁷:

PP Proteomics in systems biology (Wienkoop, Egelhofer, Weckwerth), 10 ECTS (6h)

VO Plant Metabolism – Plant systems biology: modern methods in systems biology, metabolomics, proteomics (Weckwerth, Hadacek, Wienkoop), 3 ECTS (2h)

PP Bioinformatics in Mass Spectrometry (Egelhofer, Weckwerth), 10 ECTS (6h)

PP Metabolomics (Wienkoop, Weckwerth), 10 ECTS (6h)

Systems biology publications: 9

Agrawal, G. K., Job, D., Zivy, M., Agrawal, V. P., Bradshaw, R. A., Dunn, M. J., Haynes, P. A., van Wijk, K. J., Kikuchi, S., Renaut, J., Weckwerth, W. and Rakwal, R., 2011, Time to articulate a vision for the future of plant proteomics – A global perspective: An initiative for establishing the International Plant Proteomics Organization (INPPO), *Proteomics* 11(9), 1559-1568.

⁵⁶ Source: <http://online.univie.ac.at/vlvz?extended=Y>, accessed June 30th, 2011.

⁵⁷ Source: <http://online.univie.ac.at/vlvz?extended=Y>, accessed June 20th, 2011.

- Weckwerth, W., 2011, Unpredictability of metabolism-the key role of metabolomics science in combination with next-generation genome sequencing, *Analytical and Bioanalytical Chemistry* 400(7), 1967-1978.
- Wienkoop, S., Baginsky, S. and Weckwerth, W., 2010, *Arabidopsis thaliana* as a model organism for plant proteome research, *Journal of Proteomics* 73(11), 2239-2248.
- Weckwerth W., 2010, Metabolomics: an integral technique in systems biology, *Bioanalysis* 2(4), 829-36.
- Kempa, S., Hummel, J., Schwemmer, T., Pietzke, M., Strehmel, N., Wienkoop, S., Kopka, J. and Weckwerth, W., 2009, An automated GCxGC-TOF-MS protocol for batch-wise extraction and alignment of mass isotopomer matrixes from differential (13)C-labelling experiments: a case study for photoautotrophic-mixotrophic grown *Chlamydomonas reinhardtii* cells, *Journal of Basic Microbiology* 49(1), 82-91.
- Lehmann, U., Wienkoop, S., Tschoep, H. and Weckwerth, W., 2008, If the antibody fails – a mass Western approach, *Plant Journal* 55(6), 1039-1046.
- Hoehenwarter, W., van Dongen, J. T., Wienkoop, S., Steinfath, M., Humme, J., Erban, A., Sulpice, R., Regierer, B., Kopka, J., Geigenberger, P. and Weckwerth, W., 2008, A rapid approach for phenotype-screening and database independent detection of cSNP/protein polymorphism using mass accuracy precursor alignment, *Proteomics* 8(20), 4214-4225.
- Weckwerth, W., Baginsky, S., van Wijk, K., Heazlewood, J. L. and Millar, H., 2008, The Multinational Arabidopsis Steering Subcommittee for Proteomics assembles the largest proteome database resource for plant systems biology, *Journal of Proteome Research* 7(10), 4209-4210.
- Wienkoop, S., Morgenthal, K., Wolschin, F., Scholz, M., Selbig, J. and Weckwerth, W., 2008, Integration of metabolomic and proteomic phenotypes, *Molecular & Cellular Proteomics* 7(9), 1725-1736.

5.2.4 Institute for Medical Genome Research and Systems Biology (IMGuS)

Short description: The Institute for Medical Genome Research and Systems Biology (IMGuS) is headed by Nikolaus Zacherl. It has only been realised in a reduced form. The website lists one project, namely 'Systems Biology of Steatohepatitis' (see also below).

Address: n/a

Website: http://imgus.at/index.php?cat=02_Welcome

Founded: n/a

Systems biology since: 2006*

Head: Nikolaus Zacherl

Systems biology researchers: n/a

Type: n/a

Disciplinary profile: medical genome research, systems biology

Systems biology research projects:

'Systems Biology of Steatohepatitis': funding n/a

'Systems Biology of Prostate Cancer': Nationalstiftung für Forschung, Technologie & Entwicklung and Austria Wirtschaftsservice (AWS)

Courses in systems biology: n/a

Systems biology publications: 0

5.3 Research groups

5.3.1 @ Research Institute of Molecular Pathology (IMP)

Short description: The Research Institute of Molecular Pathology (IMP) was founded in 1985 and is sponsored by the pharmaceutical company Boehringer Ingelheim GmbH & Co KG – but independent in research and governance. Together with Max F. Perutz Laboratories (MFPL), the Institute of Molecular Biotechnology (IMBA), the Gregor Mendel Institute (GMI) and several Biotech companies, the IMP is part of the Campus Vienna Biocenter. Furthermore the IMP shares several so called ‘core facilities’ with other research institutes at the campus.

More than 200 people work at the IMP (including scientific, administrative and technical staff). Managing directors are Barry Dickson and Harald Ise-
mann. Systems biology research probably started in 2008, when the Alexander Stark – research group was first mentioned in the annual reports. Furthermore, Karl Mechtler (Head of the Mass Spectrometry & Protein Chemistry) published a paper in the field of systems biology. In total, 20 research groups work at the IMP.

Address: Dr. Bohr-Gasse 7, A-1030 Vienna

Website: <http://www.imp.ac.at/>

Founded: 1985

Systems biology since: 2008*

Heads: Barry Dickson, Harald Ise-
mann (Managing Directors)

Systems biology researchers: Alexander Stark, Karl Mechtler

Type: independent research institute mainly funded by Boehringer Ingelheim

Disciplinary profile (systems biology): molecular biology, bioinformatics

Systems biology research groups:

Stark group

Mechtler group

Systems biology research projects:

MEIOSYS (FP7-KBBE)

REGULATORY GENOMICS (FP7-IDEAS)

APO-SYS (FP7-HEALTH)

MITOSYS (FP7-HEALTH)

GENCODYS (FP7-HEALTH)

EPIGENESYS (FP7-HEALTH)

Austrian Proteomics Platform II (FFG, GEN-AU)

Austrian Proteomics Platform III (FFG, GEN-AU)

Austrian Network for Functional Mouse Genomics II (FFG, GEN-AU)

Courses in systems biology: n/a

Systems biology publications: 1

Kocher, T., Pichler, P., Swart, R. and Mechtler, K., 2011, Quality control in LC-MS/MS, *Proteomics* 11(6), 1026-1030

5.3.2 @ Department of Biotechnology/ University of Natural Resources and Life Sciences (BOKU)

Short description: The Department of Biotechnology was established with the Institute of Applied Microbiology in 1945 and focuses on research in the field of Biotechnology. Karola Vorauer Uhl is the current head of the Institute of Applied Microbiology. The institute consists of several working groups, one of them called ‘Systems Biology’ led by Reingard Grabherr. Since 2005, the Department has a WWTF endowment, establishing the Chair of Bioinformatics (BI).

Address: Muthgasse 11, A-1190 Vienna

Website: <http://www.systemsbiology.at>,
<http://www.biotec.boku.ac.at/333.html?&L=1>

Founded: 1945

Systems biology since: 2003*

Head: Karola Vorauer-Uhl

Systems biology researchers: Reingard Grabherr, Wolfgang Ernst,
David P. Kreil

Type: university department – research, education

Disciplinary profile: biotechnology; applied microbiology and virology

Systems biology research groups:

Systems Biology Group

Chair in Bioinformatics (and Systems Biology)

Systems biology research projects funded by the EU, ERASysBio,
FWF or FFG:

‘Stiftungsprofessur’/working group ‘bioninformatics/systems biology’ (WWTF)

Courses in systems biology:

VO Systembiologie (Reingard Grabherr) 3 ECTS (2h)

Publications: 1

Auburn, R.P., Kreil, D.P., Meadows, L.A., Fischer, B., Matilla, S.S., Russell, S., 2005, Robotic spotting of cDNA and oligonucleotide microarrays, Trends in Biotechnology 23 (7), 374-379.

5.3.3 @ The Institute of Science and Technology Austria (IST Austria)

Short description: The Institute of Science and Technology Austria (IST Austria) is a Ph.D. granting research and educational institution. Research at IST Austria is located in the field of basic natural and mathematical sciences (up to now mainly in the fields of evolutionary biology, cell biology and biophysics, neuroscience, computer science). The current president is Thomas A. Henzinger. The institute is not organised in departments but in independent research groups with the goal of enhancing inter- and multidisciplinary research. At the moment, 17 research groups exist, of which two explicitly perform research in the area of systems biology, namely the Bollenbach and Guet Group. Furthermore, the Henzinger Group published a paper in the field of systems biology.

Address: Am Campus 1, A-3400 Klosterneuburg

Website: <http://www.ist.ac.at/>

Founded: 2009

Systems biology since: 2009

Head: Thomas A. Henzinger (president)

System biology researchers: Calin C. Guet, Tobias Bollenbach

Type: research & education institution (funded by the federal government Austrian & third-party funds)

Disciplinary profile (systems biology): molecular (cell) biology, biophysics

Systems biology research groups:

Bollenbach Group: Biophysics and Systems Biology

Guet Group: Systems and Synthetic Biology of Genetic Networks

Henzinger Group: Design and Analysis of Concurrent and Embedded Systems

Systems biology research projects:

QUAREM (ERC Advanced Grant)

Courses in systems biology: n/a

Publications: 1

Mateescu, M., Wolf, V., Didier, F. and Henzinger, T. A., 2010, Fast adaptive uniformisation of the chemical master equation, *Iet Systems Biology* 4(6), 441-452.

5.3.4 @ Johann Radon Institute for Computational and Applied Mathematics (RICAM)/Austrian Academy of Sciences

Short description: RICAM (Johann Radon Institute for Computational and Applied Mathematics) was founded in 2003 at the Austrian Academy of Sciences. It has several research groups and about 66 staff members. The research group 'Mathematical Methods in Molecular and Systems Biology' has seven staff members and first publications root back to 2008. Research group leaders are Christian Schmeiser and Philipp K  gler.

Address: Altenbergerstra   69, A-4040 Linz, Austria

Website: <http://www.ricam.oeaw.ac.at/>

Founded: 2003

Systems biology since: 2008*

Head: Heinz W. Engl

Systems biology researchers: Christian Schmeiser, Philipp K  gler, James Lu

Type: research institute

Disciplinary profile: mathematics (systems biology modelling)

Systems biology research groups:

'Mathematical Methods in Molecular and Systems Biology'

Systems biology research projects:

Elucidating spatio-temporal coherence of cellular processes by data-driven inverse analysis: redox rhythmicity in yeast and diffusion controlled hormone feedback cycles (WWTF)

Courses in systems biology:

In 2007/2008 the RICAM institute held a special semester on quantitative Biology analyzed by Mathematical Methods. Biologists, physicists and mathematicians have been invited to discuss on problems in quantitative biology with a focus on bioimaging, biomechanics and chemotaxis, ion channels, pattern formation – and functional morphology and systems biology. Please see the Annex for more details.

Publications: 4

Lu, James (2009) Inverse eigenvalue problems for exploring the dynamics of systems biology models. *Advances in Applied Mathematics and Mechanics*, Bd. 1 (6).

Heinz W. Engl, Christoph Flamm, James Lu, Philipp Kügler, Stefan Müller, Peter Schuster (2009) Inverse problems in systems biology. *Inverse Problems*, Bd. 25 (12), S. 123014.

H.W. Engl, S. Müller, J. Lu, P. Kügler (2008) Parameter identification in systems biology: solving ill-posed inverse problems using regularization. *RICAM Report* 2008-25.

Flamm, C., Endler, L., Muller, S., Widder, S. and Schuster, P., 2007, A minimal and self-consistent in silico cell model based on macromolecular interactions, *Philosophical Transactions of the Royal Society B-Biological Sciences* 362(1486), 1831-1839.

5.3.5 @ Oncotyrol – Center for Personalized Cancer Medicine

Short description: Oncotyrol Center for Personalized Cancer Medicine is a private limited liability company with following shareholders: Medical University of Innsbruck, Leopold-Franzens University of Innsbruck, Tyrolean Health Insurance Fund (TILAK GmbH), Province of Tyrol (represented by: Tiroler Zukunftsstiftung/Location Agency for Business and Science and UMIT – University for Health Sciences, Medical Informatics and Technology) and CEMIT – Center of Excellence in Medicine and IT GmbH. It was founded in October 2010 with a duration time of four years (for the time being). In total, 85 people work at Oncotyrol. There is no information available how many of them are involved in Area 5 (Bioinformatics & Systems Biology). The following (research) goal is stated by the company: “ONCOTYROL is an international partnership between academia and industry set up to accelerate the development and evaluation of individualized cancer therapies, along with diagnostic, prognostic and preventative tools.”⁵⁸ Scientific head is Lukas Huber (Director of the Division of Cell biology at the Biocenter Innsbruck, Austria) and key people in systems biology research are Zlatko Trajanoski, Armin Graber, Matthias Dehmer and Reinhard Kofler.

Address: Karl-Kapferer-Straße 5, A-6020 Innsbruck

Website: www.oncotyrol.at

Founded: 2008

Systems biology since: 2008

Heads: Bernhard Hofer (CEO), Lukas A. Huber (CSO)

Systems biology researchers: Zlatko Trajanoski, Armin Graber, Matthias Dehmer, Reinhard Kofler

Type: research company

Disciplinary profile: bioinformatics, molecular biology data analysis

Systems biology research groups:

Area 5: Bioinformatics & Systems Biology

Systems biology research projects: n/a

Courses in systems biology: n/a

Publications: 0

⁵⁸ Source: http://www.oncotyrol.at/upload/file/Oncotyrol_Firmenprofil_2010_engl.pdf, accessed July 10th, 2011.

5.3.6 @ Department of Pathophysiology and Allergy Research/Medical University of Vienna

Short description: The Department of Pathophysiology and Allergy Research at the Medical University was originally founded in 2000, but the website gives no information when it started to do research on systems biology. In total, the department has 21 research groups; one of them in the field of systems biology namely ‘Molecular Systems Biology and Pathophysiology’, headed by Diana Mechtcheriakova.

Address: Währinger Gürtel 18-20, A-1090 Vienna

Website: <http://www.meduniVienna.ac.at/orgs/index.php?id=2461>

Founded: 2000

Systems biology since: n/a

Head: Erika Jensen-Jarolim

Systems biology researchers: Diana Mechtcheriakova

Type: university department – research, education

Disciplinary profile: medical molecular biology

Systems biology research groups:

Diana Mechtcheriakova: Molecular Systems Biology and Pathophysiology

Systems biology research projects:

NUCSYS (FP6-MOBILITY)

Courses in systems biology: n/a

Publications: 0

6 Category II institutions

6.1 Academic societies & networks

6.1.1 Austrian Proteomics Platform (APP) I – III (1/2003 – 3/2012)

Short description: The Austrian Proteomics Platform (APP) is a network funded by GEN-AU (FFG) and dedicated to research in the field of proteomics. In total, there are three funding periods. All three platform projects were coordinated by Lukas A. Huber (Division of Cell Biology, Innsbruck Medical University). Only APP II and APP III include an explicit reference to systems biology; therefore APP I is not mentioned within the descriptions of the relating institutions.

Austrian Proteomics Platform I (1/2003 – 3/2006; 1.977 310 €)⁵⁹

Subproject '*Introducing New Proteomic Strategies in Veterinary Medicine*' (coordination: Ingrid Miller; Inst. for Medical Chemistry, University of Veterinary Medicine Vienna)

Subproject '*Novel Proteomics Tools*' (coordination: Karl Mechtler; IMP – Research Institute of Molecular Pathology)

Subproject '*Pharmaco-Proteomic Profiling of Chemokine/Co-Receptor Responses*' (coordination: Andreas Kungl; Inst. of Pharmaceutical Sciences, Univ. of Graz)

Subproject '*Phosphoproteomics of MAPK signaling*' (coordination: Christian Huck, Lukas Alfons Huber; Inst. of Analytical Chemistry and Radiochemistry, Univ. of Innsbruck)

Austrian Proteomics Platform II (4/2006 – 5/2009; 2.250 000 €)⁶⁰

Subproject '*Aufkonzentrierungs- und Trenntechnologien für den hohen Probandendurchsatz in Proteomics, Metabolomics und Systembiologie*' (coordination: Günther Bonn, Christian Huck; Inst. of Analytical Chemistry and Radiochemistry, Univ. of Innsbruck)

Subproject '*Entwicklung selektiver Bioaffinitätsliganden und Materialien zur qualitativen und quantitativen Untersuchung post-translationaler Modifikationen*' (coordination: Wolfgang Lindner; Inst. of Analytical Chemistry, Univ. of Vienna)

Subproject '*Entwicklung von Methoden zur Aufklärung des Proteoglykanoms*' (coordination: Andreas Kungl; Inst. of Pharmaceutical Sciences, Univ. of Graz)

Subproject '*Identifizierung und Quantifizierung von post-translationalen Modifikationen*' (coordination: Karl Mechtler; IMP – Research Institute of Molecular Pathology)

Subproject '*Medizinische Proteomics*' (coordination: Giulio Superti-Furga; CeMM – Research Centre for Molecular Medicine, Austrian Academy of Sciences)

Subproject '*Phosphoproteomics: Identifizierung neuer Substrate des Epidermalen Wachstumsfaktor/MAP Kinase Signalweges*' (coordination: Lukas Alfons Huber; Div. of Cell Biology, Med. Univ. of Innsbruck)

⁵⁹ Source: <http://www.gen-au.at/projekt.jsp?projektId=27&lang=en>, accessed August 11th, 2011.

⁶⁰ Source: <http://www.gen-au.at/projekt.jsp?projektId=52&lang=en>, accessed August 11th, 2011.

Austrian Proteomics Platform III (4/2009-3/2012, 1.350 000 €)⁶¹

Subproject ‘*Chromatography, stationary phases, ESI-MS/MS, MALDI-TOF, MELDI, IR spectroscopy*’ (coordination: Günther Bonn, Inst. of Analytical Chemistry and Radiochemistry, Univ. of Innsbruck)

Subproject ‘*Glyco-proteomics, protein complexes, biophysics, protein engineering, bioinformatics*’ (coordination: Andreas Kungl; Inst. of Pharmaceutical Sciences, Univ. of Graz)

Subproject ‘*Interaction proteomics (TAP-tagging), drug proteomics, mass spectrometry, signal transduction, kinases*’ (coordination: Giulio Superti-Furga; CeMM – Research Centre for Molecular Medicine, Austrian Academy of Sciences)

Subproject ‘*Qualitative and quantitative proteomics, top-down proteomics of intact proteins, multidimensional chromatography, mass spectrometry of biopolymers, bioinformatic tools for proteome analysis*’ (coordination: Christian Huber; Dept. of Molecular Biology, Univ. of Salzburg)

Subproject ‘*Quantitative MS of post translational modifications, chromatography, mass spectrometry, interaction proteomics, top down proteomics*’ (coordination: IMP – Research Institute of Molecular Pathology)

Subproject ‘*Signal transduction, mouse genetics, organelle- and phospho-proteomics, protein complexes, 2D-DIGE, MALDI-TOF*’ (coordination: Lukas Alfons Huber; Inst. of Analytical Chemistry and Radiochemistry, Univ. of Innsbruck)

Subproject ‘*Tagging chemistries and affinity materials for proteome analysis, chiral separations, capillary separation techniques and hyphenation of such techniques to mass spectrometry*’ (coordination: Wolfgang Lindner; Inst. of Analytical Chemistry, Univ. of Vienna)

6.1.2 Bioinformatics Integration Network (BIN) I – III

Short description: The Bioinformatics Integration Network (BIN) is a network funded by GEN-AU (FFG). It aims at integrating “the young Austrian bioinformatics research community” by “establishing bioinformatics services, research, networking, training for both researchers and industry”, an “Open Source platform of freely available source code” for an integrative research programme and “a national virtual laboratory”.⁶² In total, there are three funding periods. All three network projects were coordinated by Zlatko Trajanoski (2004-2010: Institute for Genomics and Bioinformatics, Graz University of Technology; 2010 – now: Section for Bioinformatics, Innsbruck Medical University).

BIN I – III do not include an explicit reference to systems biology, although they are seen as a major contribution to the establishment of systems biology in Austria by some experts; therefore, they are presented here, but not mentioned within the descriptions of the relating institutions.

⁶¹ Source: <http://www.gen-au.at/projekt.jsp?projektId=111&lang=en>, accessed August 11th, 2011.

⁶² <http://www.gen-au.at/projekt.jsp?projektId=53&lang=en>, accessed Feb. 4th, 2012.

Bioinformatics Integration Network I (1/2003 – 12/2005; 1.733 952 €)⁶³

“During this phase we established three thematic nodes with complementary expertise: (i) bioinformatics services and database integration, (ii) sequence annotation and (iii) structural genomics.”⁶⁴

Subproject ‘*Bioinformatics Services and Database Integration*’ (coordination: Zlatko Trajanoski, Reinhard Kofler; Inst. for Genomics and Bioinformatics, TU Graz; Tyrolean Cancer Research Institute)

Subproject ‘*In Silico Target Identification and Function Prediction*’ (coordination: Frank Eisenhaber; IMP – Research Institute of Molecular Pathology)

Subproject ‘*Rechnergestützte Strukturgenomik*’ (coordination: Peter Schuster, Christoph Kratky; Inst. for Theoretical Chemistry, Univ. of Vienna; Inst. for Chemistry, Univ. of Graz)

Bioinformatics Integration Network II (12/2005 – 11/2008; 2.542 380 €)⁶⁵

“During the second funding period we expanded and improved the backbone for bioinformatics services and broadened the scope of the thematic nodes by establishing proteomics informatics and evolutionary sequence analysis.”⁶⁶

Subproject ‘*Administration and Coordination*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz)

Subproject ‘*Databases and Analytical Tools for Genomics and Proteomics*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz)

Subproject ‘*Function Prediction with Biomolecular Sequence Analysis and Mass Spectrometry Data Interpretation*’ (coordination: Frank Eisenhaber; IMP – Research Institute of Molecular Pathology)

Subproject ‘*Modeling and Inferring the Dynamics of Sequence Evolution*’ (coordination: Arndt von Haeseler; Center for Integrative Bioinformatics, Max F. Perutz Laboratories)

Subproject ‘*RNA related Bioinformatics Tools*’ (coordination: Ivo Hofacker, Peter Schuster; Inst. for Theoretical Chemistry, Univ. of Vienna)

Subproject ‘*Computational Structural Genomics*’ (coordination: Kristina Djinovic-Carugo, Oliviero Carugo; Dept. of Biomolecular Structural Chemistry, Univ. of Vienna)

Subproject ‘*Data Mining in Proteomics*’ (coordination: Bernhard Tilg, Armin Graber; Medical Informatics and Technology, UMIT)

Subproject ‘*Education and Training (International PhD Programme)*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz)

Bioinformatics Integration Network III (1/2009 – 12/2011; 1.840 000 €)⁶⁷

“The continuous development and application of novel technologies for generating high-throughput data requires the parallel development of computational methods and tools to manage, store, and analyze the data. The BIN III consortium therefore plans to maintain and enrich the computational laboratory and strengthen interactions with the experimental partners during the third

⁶³ <http://www.gen-au.at/projekt.jsp?projektId=26&lang=en>, accessed Feb. 4th, 2012.

⁶⁴ <http://bin.tugraz.at/>, accessed Feb. 4th, 2012.

⁶⁵ <http://www.gen-au.at/projekt.jsp?projektId=53&lang=en>, accessed Feb. 4th, 2012.

⁶⁶ <http://bin.tugraz.at/>, accessed Feb. 4th, 2012.

⁶⁷ <http://www.gen-au.at/projekt.jsp?projektId=53&lang=en>, accessed Feb. 4th, 2012.

funding period. The goal of the BIN III project is to provide bioinformatics services and use computational methods to address biological questions arising from the GEN-AU projects.”⁶⁸

Subproject ‘*Central infrastructure, administration, and coordination*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz & Section for Bioinformatics, Innsbruck Medical University)

Subproject ‘*Biomolecular networks in cell differentiation and cancer*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz & Section for Bioinformatics, Innsbruck Medical University)

Subproject ‘*Cis-acting regulatory motifs*’ (coordination: Alexander Stark, Maria Novatchkova; IMP – Research Institute of Molecular Pathology)

Subproject ‘*Modeling and inferring the dynamics of sequence evolution*’ (coordination: Arndt von Haeseler; Center for Integrative Bioinformatics, Max F. Perutz Laboratories)

Subproject ‘*RNA related bioinformatics tools*’ (coordination: Ivo Hofacker; Inst. for Theoretical Chemistry, Univ. of Vienna)

Subproject ‘*Computational structural genomics*’ (coordination: Kristina Djinovic-Carugo, Oliviero Carugo; Dept. of Biomolecular Structural Chemistry, Univ. of Vienna)

Subproject ‘*Data mining for cancer and cardiovascular diseases*’ (coordination: Christian Baumgartner, Armin Graber; Medical Informatics and Technology, UMIT)

Subproject ‘*Integration and mining of drug-, protein-, and gene- interaction data*’ (coordination: Jacques Colinge, Keiryn Lynn Bennett; CeMM – Research Centre for Molecular Medicine; Austrian Academy of Sciences)

Subproject ‘*Education und training*’ (coordination: Zlatko Trajanoski; Inst. for Genomics and Bioinformatics, TU Graz & Section for Bioinformatics, Innsbruck Medical University)

6.2 Institutions (centers, departments, institutes, companies)

6.2.1 Department of Medicinal Chemistry/University Vienna

Short description: At the Department of Medicinal Chemistry, research focuses on several areas of medical/pharmaceutical chemistry. The department in its current structure was founded in 2005 (the former Institute of Pharmaceutical Chemistry was split up into three departments) and is headed by Christian Noe. Noe is also an active promoter of systems biology and systems pharmacology at the international level (e.g. via IMI – The Innovative Medicines Initiative⁶⁹).

Address: Althanstraße 14, A-1090 Vienna

⁶⁸ <http://bin.tugraz.at/>, accessed Feb. 4th, 2012.

⁶⁹ <http://www.imi.europa.eu/>, accessed April 4th, 2012. “IMI (2007), is a major joint effort planned by the European Commission and the European Pharmaceutical Industry Association (EFPIA 2007). The objective of IMI is to support the faster discovery and development of better medicines for patients and to enhance Europe’s competitiveness by ensuring that its biopharmaceutical sector remains a dynamic high-technology sector. IMI has been accepted as a Joint Technology Initiative by the European Council and European Parliament in 2008.” (Marcus 2007: 162)

Website: <http://merian.pch.univie.ac.at/pch/medchem/>

Founded: 2005

Systems biology since: n/a

Head: Christian R. Noe

Systems biology researchers: Christian R. Noe, Johannes Winkler

Type: university institute – research, education

Systems biology research groups:

Thematic research line ‘Systems Biology in Drug Research (Pharmaceutical Systems Biology)’; Christian R. Noe, Johannes Winkler

Systems biology projects: n/a

Courses in systems biology: n/a

Systems biology publications: 1

Westerhoff, H. V., Mosekilde, E., Noe, C. R. and Clemensen, A. M., 2008, Integrating systems approaches into pharmaceutical sciences, *European Journal of Pharmaceutical Sciences* 35(1-2), 1-4.

6.2.2 Department of Genetics in Ecology/University Vienna

Short description: Christa Schleper is head of the Department of Genetics in Ecology at the University Vienna. She was the main coordinator of the European project SulfoSYS (‘Silicon Cell Model for the central carbohydrate metabolism of the archaeon *Sulfolobus solfataricus* under temperature variation’) within SysMO (Systems Biology of Microorganisms) from 2007 until 2010.

Address: Althanstraße 14, A-1090 Vienna

Website: <http://genetics-ecology.univie.ac.at/index.html>

Founded: 2007

Systems biology since: 2007*

Head: Christa Schleper

Systems biology researchers: Christa Schleper

Type: university institute – research, education

Disciplinary profile: medical molecular biology

Systems biology projects: SulfoSYS (SysMO)⁷⁰

Courses in systems biology: n/a

Systems biology publications: 0

6.2.3 Department of Theoretical Biology/University Vienna

Short description: Head of the Department of Theoretical Biology is Gerd B. Müller. Research at the department is dedicated to „(...) theoretical biology of EvoDevo using developmental imaging, biometrics, and the integration of evolutionary theories.”⁷¹ Manfred Drack is a post-doc researcher at the department and has just started a project on systems biology (see below).

Address: Althanstraße 14, A-1090 Vienna

⁷⁰ Christa Schleper started coordination of this project from the University of Bergen, moving to the University of Vienna in 2007.

⁷¹ Source: <http://theoretical.univie.ac.at/home/>, accessed Oct. 10th, 2011.

Website: <http://theoretical.univie.ac.at/home/>

Founded: 2005

Systems biology since: 2011*

Head: Gerd B. Müller

Systems biology researchers: Manfred Drack

Type: university institute – research, education

Disciplinary profile: theoretical biology, philosophy of biology

Systems biology projects: ‘Systeme in der Biologie’ (FWF)

Courses in systems biology: n/a

Systems biology publications: 1

Drack, M., Apfalter, W. and Pouvreau, D., 2007, On the making of a system theory of life: Paul A. Weiss and Ludwig von Bertalanffy’s conceptual connection, *Quarterly Review of Biology* 82(4), 349-373.

6.2.4 Institute for Theoretical Chemistry/University Vienna

Short description: The Institute for Theoretical Chemistry was founded in 1968 and is headed by Ivo Hofacker (professorships at the faculties of chemistry and computer science). Peter Schuster is emeritus professor and publishes papers on systems biology. Christoph Flamm gives courses in systems biology and was involved in a systems biology-related project funded by the WWTF.

Address: Währinger Straße 17, A-1090 Vienna

Website: <http://www.itc.univie.ac.at/index.html>

Founded: 1968

Systems biology since: n/a

Head: Ivo Hofacker

Systems biology researchers: Christoph Flamm, Peter Schuster, Bernd Mayer

Type: university department – research & education

Disciplinary profile: theoretical chemistry

Systems biology relevant research groups

Theoretical Biochemistry (TBI) research group

Systems biology projects: n/a

Courses in systems biology: VO Grundlagen der Systembiologie (English: Basics of systems biology) (Flamm), 2h

Systems biology publications: 9

Meisner, N. C., Hackermüller, J., Uhl, V., Aszodi, A., Jaritz, M. and Auer, M., 2004, mRNA openers and closers: Modulating AU-rich element-controlled mRNA stability by a molecular switch in mRNA secondary structure, *ChemBiochem* 5(10), 1432-1447.

Engl, H. W., Flamm, C., Kugler, P., Lu, J., Müller, S. and Schuster, P., 2009, Inverse problems in systems biology, *Inverse Problems* 25, 123014.

Schuster, P., 2008, Modeling in biological chemistry. From biochemical kinetics to systems biology, *Monatshefte Für Chemie* 139(4), 427-446.

Machne, R., Finney, A., Müller, S., Lu, J., Widder, S. and Flamm, C., 2006, The SBML ODE Solver Library: a native API for symbolic and fast numerical analysis of reaction networks, *Bioinformatics* 22(11), 1406-1407.

Platzner, A., Perco, P., Lukas, A. and Mayer, B., 2007, Characterization of protein-interaction networks in tumors, *Bmc Bioinformatics* 8, 224.

Flamm, C., Endler, L., Muller, S., Widder, S. and Schuster, P., 2007, A minimal and self-consistent in silico cell model based on macromolecular interactions, *Philosophical Transactions of the Royal Society B-Biological Sciences* 362(1486), 1831-1839.

Perco, P., Wilflingseder, J., Bernthaler, A., Wiesinger, M., Rudnicki, M., Wimmer, B., Mayer, B. and Oberbauer, R., 2008, Biomarker candidates for cardiovascular disease and bone metabolism disorders in chronic kidney disease: a systems biology perspective, *Journal of Cellular and Molecular Medicine* 12(4), 1177-1187.

Perco, P., Muhlberger, I., Mayer, G., Oberbauer, R., Lukas, A. and Mayer, B., 2010, Linking transcriptomic and proteomic data on the level of protein interaction networks, *Electrophoresis* 31(11), 1780-1789.

Perco, P., Rapberger, R., Siehs, C., Lukas, A., Oberbauer, R., Mayer, G. and Mayer, B., 2006, Transforming omics data into context: Bioinformatics on genomics and proteomics raw data, *Electrophoresis* 27(13), 2659-2675.

6.2.5 Max F. Perutz Laboratories (MFPL)

Short description: In 2005, the Max F. Perutz Laboratories were founded by the University Vienna and the Medical University of Vienna as a joint venture. Graham Warren (Scientific Director) and Fabien Martins (Administrative Director) are the heads of about 50 research groups in the field of molecular biology. The groups led by Karl Kuchler and Heribert Hirt focus on systems biology research.

Address: Dr. Bohr-Gasse 9, A-1030 Vienna

Website: <http://www.mfpl.ac.at/>

Founded: 2005

Systems biology since: 2005*

Head: Graham Warren (Scientific Director),
Fabien Martins (Administrative Director)

Systems biology researchers: Karl Kuchler, Heribert Hirt, Walter Glaser, Martin Valachovic

Type: research institute (joint venture University of Vienna & Medical University Vienna)

Disciplinary profile: molecular biology

Systems biology relevant research groups:

Group Kuchler (with a link to the Kuchler laboratory at the Medical Univ. of Vienna)

Group Hirt

Systems biology projects⁷²:

UNICELLSYS (FP7-HEALTH)

YSBN (FP6-LIFESCIHEALTH)

EUSYSBIO (FP6-LIFESCIHEALTH)

MOSES (SysMO)

TRANSLUCENT (SysMO)⁷³

⁷² Projects of both, Kuchler laboratory at the Medical Univ. of Vienna and Group Kuchler at the MFPL are mentioned here.

⁷³ Participation by Rudolf J. Schweyen, then affiliated with the Univ. of Vienna and MFPL.

Courses in systems biology: Karl Kuchler co-organises the biannual FEBS (Federation of the European Biochemical Societies) “Advanced Lecture Course on Systems Biology”

Systems biology publications: 4

van Bentem, S. D., Mentzen, W. I., de la Fuente, A. and Hirt, H., 2008, Towards functional phosphoproteomics by mapping differential phosphorylation events in signaling networks, *Proteomics* 8(21), 4453-65.

Pflieger, D., Gonnet, F., van Bentem, S. D., Hirt, H. and de la Fuente, A., 2011, LINKING THE PROTEINS-ELUCIDATION OF PROTEOME-SCALE NETWORKS USING MASS SPECTROMETRY, *Mass Spectrometry Reviews* 30(2), 268-297.

Pitzschke, A. and Hirt, H., 2010, Bioinformatic and Systems Biology Tools to Generate Testable Models of Signaling Pathways and Their Targets, *Plant Physiology* 152(2), 460-469.

Pieroni, E., Van Bentem, S. D., Mancosu, G., Capobianco, E., Hirt, H. and de la Fuente, A., 2008, Protein networking: insights into global functional organization of proteomes, *Proteomics* 8(4), 799-816.

6.2.6 *Institute of Technology Assessment (ITA)/ Austrian Academy of Sciences*

Short description: The Institute of Technology Assessment (ITA) was founded in 1994 at the Austrian Academy of Sciences. It is an interdisciplinary research institute focusing on the study of technological change and its societal conditions, options and impacts. Since 2006, Michael Nentwich is head of the institute. Currently, two projects on systems biology are conducted at the institute (‘Reflexive Systems Biology’, funded by the Norwegian Forskningsrådet and THCL, funded by the FFG).

Address: Strohlg. 45/5, A-1030 Vienna

Website: <http://www.oew.ac.at/ita/>

Founded: 1994

Systems biology since: 2009

Head: Michael Nentwich

Systems biology researchers: Karen Kastenhofer, Helge Torgerson

Type: research institute

Disciplinary profile: science and technology studies

Systems biology projects: THCL (GEN-AU, FFG)

Courses in systems biology: n/a

Systems biology publications: 1

Torgersen, H., 2009, Fuzzy Genes: Epistemic Tensions in Genomics, *Science as Culture* 18(1), 65-87.

6.2.7 *Institute for Bioinformatics and Translational Research/UMIT*

Short description: The Institute for Bioinformatics and Translational Research at the Health and Life Sciences University Hall/Tirol (UMIT) is headed by Matthias Dehmer. Armin Graber holds a chair in bioinformatics at the institute. Both researchers are also involved in Oncotyrol projects (see Oncotyrol).

Address: Eduard Wallnöfer-Zentrum 1, A-6060 Hall in Tirol

Website: <http://www.umat.at/page.cfm?vpath=departments/technik/bioinf&expanddiv=subDeptItem343>

Founded: 2011

Systems biology since: 2011

Head: Mathias Dehmer

Systems biology researchers: Mathias Dehmer, Armin Graber

Systems biology research groups

Research area 'Systems Biology and Dynamical Systems'

Systems biology projects: n/a

Courses in systems biology: n/a

Systems biology publications: 5

Modre-Osprian, R., Osprian, I., Tilg, B., Schreier, G., Weinberger, K. M. and Graber, A., 2009, Dynamic simulations on the mitochondrial fatty acid Beta-oxidation network, *Bmc Systems Biology* 3, 2.

Emmert-Streib, F. and Dehmer, M., 2011, Networks for systems biology: conceptual connection of data and function, *Iet Systems Biology* 5(3), 185-207.

Balasubramanian R, Mueller L, Kugler K, Hackl W, Pleyer L, Dehmer M, Graber A.: The impact of storage effects in biobanks on biomarker discovery in systems biology studies. *Biomarkers*. 15(8), 677-83.

Molina, F., Dehmer, M., Perco, P., Graber, A., Girolami, M., Spasovski, G., Schanstra, J. P. and Vlahou, A., 2010, Systems biology: opening new avenues in clinical research, *Nephrology Dialysis Transplantation* 25(4), 1015-1018.

Dominiczak AF, Herget-Rosenthal S, Delles C, Fliser D, Fournier I, Graber A, Girolami M, Holmes E, Lang F, Molina F, Nicholson J, Remuzzi G, Rossing P, Rudolph KL, Wolkenhauer O, Xenarios I, Zubarev R, Zubov D, Vlahou A, Schanstra JP.: Systems biology to battle vascular disease, *Nephrol Dial Transplant*. 25 (4), 1019-1022.

6.2.8 Software Competence Center Hagenberg (SCCH)

Short description: The Software Competence Center Hagenberg (SCCH) is an application orientated research company founded in 1999. The company is owned by the Johannes Kepler University Linz (1/3), the Upper Austrian Research GmbH (1/3) and the 'Verein der Partnerfirmen des SCCH' ('association of SCCH associated companies') (1/3). It employs about 60 staff members. In fiscal year 2009/2010, SCCH reached a performance of 5.1 million Euros. It cooperates with more than 28 international research institutes and reference customers like Siemens AG, Fronius International GmbH or the Upper Austrian Insurance Company. Since 2009, it is coordinator and partner of the project *Cancermotisys* with Julian Mattes as project leader and Matej Smid, Tomas Kazmar and Martina Schwendinger as project members.

Address: Softwarepark 21, A-4232 Hagenberg

Website: <http://www.scch.at/en/home>

Founded: 1999

Systems biology since: 2009

Head: Klaus Pirklbauer (CEO)

Systems biology researchers: Julian Mattes, Matej Smid, Tomas Kazmar, Martina Schwendinger

Type: research centre (owned by Johannes Kepler University Linz, Upper Austrian research GmbH, Verein der Partnerfirmen des SCCH)

Disciplinary profile: computer science and mathematics (software-related research)

Systems biology projects funded by the EU, ERASysBio, SysMO, FWF or FFG: CANCERMOTISYS (GEN-AU, FFG)

Courses in systems biology: n/a

Systems biology publications: Publications since 2000 with 'systems biology' in title, topic or keywords found in Web of Science⁷⁴: 0

6.2.9 Emergentec Biodevelopment GmbH

Short description: The Emergentec Biodevelopment GmbH is a research company focusing on the development of new biotech and pharma products. The managing directors Arno Lukas and Bernd Mayer founded the company in 2002. They are involved in the European Framework Programme 7 – 'Syskid'-project (see below).

Address: Gersthofer Strasse 29-31, A-1180 Vienna

Website: <http://www.emergentec.com/en/index.php>

Founded: 2002

Systems biology since: 2002*

Heads: Arno Lukas, Bernd Mayer

Systems biology researchers: Paul Perco, Martin Haiduk, Bernd Mayer, Irmgard Mühlberger, Raul Fachete, Martin Wiesinger

Type: research company

Disciplinary profile: microbial ecology, molecular biology

Systems biology projects: SYSKID (FP7-HEALTH)

Courses in systems biology: n/a

Systems biology publications: 6

Perco, P., Mühlberger, I., Mayer, G., Oberbauer, R., Lukas, A. and Mayer, B., 2010, Linking transcriptomic and proteomic data on the level of protein interaction networks, *Electrophoresis* 31(11), 1780-1789.

Perco, P., Rapberger, R., Siehs, C., Lukas, A., Oberbauer, R., Mayer, G. and Mayer, B., 2006, Transforming omics data into context: Bioinformatics on genomics and proteomics raw data, *Electrophoresis* 27(13), 2659-2675.

Platzer, A., Perco, P., Lukas, A. and Mayer, B., 2007, Characterization of protein-interaction networks in tumors, *Bmc Bioinformatics* 8, 224.

Molina, F., Dehmer, M., Perco, P., Graber, A., Girolami, M., Spasovski, G., Schanstra, J. P. and Vlahou, A., 2010, Systems biology: opening new avenues in clinical research, *Nephrology Dialysis Transplantation* 25(4), 1015-1018.

Perco, P., Wilflingseder, J., Bernthaler, A., Wiesinger, M., Rudnicki, M., Wimmer, B., Mayer, B. and Oberbauer, R., 2008, Biomarker candidates for cardiovascular disease and bone metabolism disorders in chronic kidney disease: a systems biology perspective, *Journal of Cellular and Molecular Medicine* 12(4), 1177-1187.

Rudnicki, M., Perco, P., Enrich, J., Eder, S., Heininger, D., Bernthaler, A., Wiesinger, M., Sarkozi, R., Noppert, S. J., Schramek, H., Mayer, B., Oberbauer, R. and Mayer, G., 2009, Hypoxia response and VEGF-A expression in human proximal tubular epithelial cells in stable and progressive renal disease, *Laboratory Investigation* 89(3), 337-346.

⁷⁴ Source: <http://wokinfo.com/>, 19.7.2011

6.2.10 Biocrates Life Sciences AG

Short description: The Biocrates Life Sciences AG is a company dedicated to research in the field of diagnostic biomarker research and was founded in 2002. Elgar Schnegg (since 2008 at Biocrates, before he was working in pharmaceutical industries, studied economics) is Chief Executive Officer, Klaus Weinberger (since 2003 at Biocrates, before he was research group leader at the Institute of Medical Microbiology and Hygiene at the University of Regensburg, Germany, Ph.D. in medical microbiology) is Chief Scientific Officer, and Ralph Zahn (since 2010 at Biocrates, was managing director at Biosafety GmbH, Ph.D. in biology) is Chief Technology Officer.

Address: Innrain 66/2, A-6020 Innsbruck

Website: <http://www.biocrates.com/>

Founded: 2002

Systems biology since: 2002

Heads: Elgar Schnegg (CEO), Klaus Weinberger (CSO), Ralph Zahn (CTO)

Systems biology researchers: David P. Enot, Hans-Peter Deigner, Therese Koal, Ingrid Osprian, Klaus M. Weinberger

Type: research company

Disciplinary profile: metabolomics (diagnostic biomarker research)

Systems biology projects:

METAFLUX (FP7 people)

SYSKID (FP7-HEALTH)

COBRED (FP6-LIFESCIHEALTH)

Courses in systems biology: n/a

Systems biology publications: 3

Griffiths, W. J., Koal, T., Wang, Y. Q., Kohl, M., Enot, D. P. and Deigner, H. P., 2010, Targeted Metabolomics for Biomarker Discovery, *Angewandte Chemie-International Edition* 49(32), 5426-5445.

Koal, T. and Deigner, H. P., 2010, Challenges in Mass Spectrometry Based Targeted Metabolomics, *Current Molecular Medicine* 10(2), 216-226.

Modre-Osprian, R., Osprian, I., Tilg, B., Schreier, G., Weinberger, K. M. and Graber, A., 2009, Dynamic simulations on the mitochondrial fatty acid Beta-oxidation network, *Bmc Systems Biology* 3, 2.

6.2.11 Viscovery Software GmbH

Short description: Viscovery Software GmbH is a data mining company and was founded in 1994 (formerly Eudaptics) by Gerhard Kranner. In 2007, the company was acquired by the Biomax Group, Germany. It offers data mining solutions using its developed software packages, for example the Viscovery® Suite for explorative data mining and predictive analytics with a focus on customer behavior modeling (CBM). Since 2009, Viscovery is a partner of the project *CancerMotisys*, with Svetlana Gaffron as project leader.

Address: Kupelwiesergasse 27, A-1130 Vienna

Website: <http://www.viscovery.net/>

Founded: 1994

Systems biology since: 2009

Head: Gerhard Kranner (CEO)

Systems biology researchers: Svetlana Gaffron

Type: company (part of the Biomax Group)

Disciplinary profile: computer science and mathematics (data-mining)

Systems biology projects funded by the EU, ERASysBio, SysMO, FWF or FFG:
CANCERMOTISYS (GEN-AU, FFG)

Courses in systems biology: n/a

Systems biology publications: 0

7 Category III institutions

7.1 Public research institutions: Vienna

7.1.1 Department of Limnology/University of Vienna

Address: A-1090 Vienna,

<http://www.univie.ac.at/deli/index.php/startseite.html>

Systems biology relevant experts: Tom J. Battin

Systems biology publications: 1

Battin, T. J., Sloan, W. T., Kjelleberg, S., Daims, H., Head, I. M., Curtis, T. P. and Eberl, L., 2007, Microbial landscapes: new paths to biofilm research, *Nature Reviews Microbiology* 5(1), 76-81.

7.1.2 Department of Microbial Ecology/University of Vienna

Address: A-1090 Vienna, <http://www.microbial-ecology.net/default.asp>

Systems biology relevant experts: Holger Daims

Systems biology publications: 1

Battin, T. J., Sloan, W. T., Kjelleberg, S., Daims, H., Head, I. M., Curtis, T. P. and Eberl, L., 2007, Microbial landscapes: new paths to biofilm research, *Nature Reviews Microbiology* 5(1), 76-81.

7.1.3 Department of Molecular Evolution and Development/University of Vienna

Address: A-1090 Vienna, <http://molevodevo.univie.ac.at/>

Systems biology relevant experts: Ulrich Technau

Systems biology projects: EVONET (FP7 people)

7.1.4 Department of Applied Genetics and Cell Biology (DAGZ)/BOKU

Address: A-1190 Vienna, <http://www.dagz.boku.ac.at/dagz.html?&L=1>

Systems biology relevant experts: Andrea Pitzschke

Systems biology publications: 1

Pitzschke, A. and Hirt, H., 2010, Bioinformatic and Systems Biology Tools to Generate Testable Models of Signaling Pathways and Their Targets, *Plant Physiology* 152(2), 460-469.

7.1.5 Division of Biochemistry, Dpt. Of Chemistry/BOKU

Address: A-1090 Vienna, <http://www.chemie.boku.ac.at/366.html?&L=1>

Systems biology relevant experts: Johannes Stadlmann (currently: IMP)

Systems biology publications: 1

Baumann, K., Carnicer, M., Dragosits, M., Graf, A. B., Stadlmann, J., Jouhten, P., Maaheimo, H., Gasser, B., Albiol, J., Mattanovich, D. and Ferrer, P., 2010, A multi-level study of recombinant *Pichia pastoris* in different oxygen conditions, *Bmc Systems Biology* 4, 141.

7.1.6 Institute of Applied Synthetic Chemistry/ Vienna University of Technology

Address: A-1060 Vienna, <http://www.ias.tuVienna.ac.at/>

Systems biology relevant experts: Florian Rudroff

Systems biology projects: 'Biocatalytic Redox Cascades Using Baeyer-Villiger Monooxygenase' (DACH, FWF); Schrödinger Stipendium (FWF).

7.1.7 Institute for Chemical Engineering/ Vienna University of Technology

Address: A-1060 Vienna, <http://www.vt.tuVienna.ac.at/index.php>

Systems biology relevant experts: Peter Christian Kubicek

Systems biology publications: 1

Andersen, M. R., Salazar, M. P., Schaap, P. J., van de Vondervoort, P. J. I., Culley, D., Thykaer, J., Frisvad, J. C., Nielsen, K. F., Albang, R., Albermann, K., Berka, R. M., Braus, G. H., Braus-Stromeier, S. A., Corrochano, L. M., Dai, Z. Y., van Dijck, P. W. M., Hofmann, G., Lasure, L. L., Magnuson, J. K., Menke, H., Meijer, M., Meijer, S. L., Nielsen, J. B., Samson, R. A., Stam, H., Tsang, A., van den Brink, J. M., Atkins, A., Aerts, A., Shapiro, H., Pangilinan, J., Salamov, A., Lou, Y. G., Lindquist, E., Lucas, S., Grimwood, J., Grigoriev, I. V., Kubicek, C. P., Martinez, D., van Peij, N., Roubos, J. A., Nielsen, J. and Baker, S. E., 2011, Comparative genomics of citric-acid-producing *Aspergillus niger* ATCC 1015 versus enzyme-producing CBS 513.88, *Genome Research* 21(6), 885-897.

7.1.8 Institute for Mechanics of Materials and Structures/ Vienna University of Technology

Address: A-1040 Vienna, <http://www.imws.tuVienna.ac.at/en/home.html>

Systems biology relevant experts: Herbert Mang

Systems biology projects: MICROBONE (FP7-IDEAS)

7.1.9 Institute of Cancer Research (ICR), Department of Medicine II/Medical University of Vienna

Address: A-1090 Vienna,

<http://www.meduniVienna.ac.at/krebsforschung/en/>

Systems biology relevant experts: Maria Sibilja, Robert Eferl

Systems biology relevant research groups:

[Cellular and Molecular Tumorbiology](#) Research Unit

[Applied and Experimental Oncology](#) Research Unit

Systems biology projects: Austrian Network for Functional Mouse Genomics II (GEN-AU, FFG)

7.1.10 Institute for Hygiene and Applied Immunology, Centre for Pathophysiology, Infectiology and Immunology/ Medical University of Vienna

Address: A-1090 Vienna,

<http://www.meduniVienna.ac.at/hp/en/>

[institute-for-hygiene-and-applied-immunology/](#)

Systems biology relevant experts: Hannes Stockinger

Systems biology relevant research groups:

Molecular Immunology Unit

Systems biology projects: MULTIFACETED CASR (FP7 people)

7.1.11 Nephrology & Dialysis, Department of Internal Medicine III/ Medical University of Vienna

Also: Laboratory Rainer Oberbauer, Academic Research in Genetic and Clinical Epidemiology of Kidney Disease

Address: A-1090 Vienna,

<http://www.meduniVienna.ac.at/innere3/nephro/Nephro-abt-frameset.htm>,

<http://www.meduniVienna.ac.at/nephrogene/>

Systems biology relevant experts: Rainer Oberbauer, Paul Perco

Systems biology relevant research groups:

Academic Research in Genetic and Clinical Epidemiology of Kidney Disease

Systems biology projects: SYSKID (FP7-HEALTH)

Systems biology publications: 5

Perco, P., Muhlberger, I., Mayer, G., Oberbauer, R., Lukas, A. and Mayer, B., 2010, Linking transcriptomic and proteomic data on the level of protein interaction networks, *Electrophoresis* 31(11), 1780-1789.

Perco, P., Wilflingseder, J., Bernthaler, A., Wiesinger, M., Rudnicki, M., Wimmer, B., Mayer, B. and Oberbauer, R., 2008, Biomarker candidates for cardiovascular disease and bone metabolism disorders in chronic kidney disease: a systems biology perspective, *Journal of Cellular and Molecular Medicine* 12(4), 1177-1187.

Rudnicki, M., Perco, P., Enrich, J., Eder, S., Heining, D., Bernthaler, A., Wiesinger, M., Sarkozi, R., Noppert, S. J., Schramek, H., Mayer, B., Oberbauer, R. and Mayer, G., 2009, Hypoxia response and VEGF-A expression in human

proximal tubular epithelial cells in stable and progressive renal disease, *Laboratory Investigation* 89(3), 337-346.

Molina, F., Dehmer, M., Perco, P., Graber, A., Girolami, M., Spasovski, G., Schanstra, J. P. and Vlahou, A., 2010, Systems biology: opening new avenues in clinical research, *Nephrology Dialysis Transplantation* 25(4), 1015-1018.

Perco, P., Rapberger, R., Siehs, C., Lukas, A., Oberbauer, R., Mayer, G. and Mayer, B., 2006, Transforming omics data into context: Bioinformatics on genomics and proteomics raw data, *Electrophoresis* 27(13), 2659-2675.

7.1.12 Experimental Oncology, Dpt. of Ear, Nose and Throat Diseases/Medical University of Vienna

Address: A-1090 Vienna, <http://www.meduniVienna.ac.at/hno/allgemeine-informationen/wissenschaft-forschung/experimentelle-onkologie/>

Systems biology relevant experts: Dietmar Thurnher, B. M. Erovic

Systems biology publications: 1

Koehn, J., Krapfenbauer, K., Huber, S., Stein, E., Sutter, W., Watzinger, F., Erovic, B. M., Thurnher, D., Schindler, T., Fountoulakis, M. and Turhani, D., 2008, Potential involvement of MYC- and p53-related pathways in tumorigenesis in human oral squamous cell carcinoma revealed by proteomic analysis, *Journal of Proteome Research* 7(9), 3818-3829.

7.1.13 Department of Radiology/Medical University of Vienna

Address: A-1090 Vienna, <http://www.radiodiagnostik-akhVienna.at/index.aspx>

Systems biology relevant experts: Christian J. Herold

Systems biology publications: 1

Bradley, W. G., Golding, S. G., Herold, C. J., Hricak, H., Krestin, G. P., Lewin, J. S., Miller, J. C., Ringertz, H. G. and Thrall, J. H., 2011, Globalization of P4 Medicine: Predictive, Personalized, Preemptive, and Participatory-Summary of the Proceedings of the Eighth International Symposium of the International Society for Strategic Studies in Radiology, August 27-29, 2009, *Radiology* 258(2), 571-582.

7.1.14 Section for Science of Complex Systems, Center for Medical Statistics, Informatics, and Intelligent Systems/Medical University of Vienna

Formerly Complex Systems Research Group (COSY)

Address: A-1090 Vienna, <http://www.complex-systems.meduniVienna.ac.at/about/>

Systems biology relevant experts: Stefan Thurner, Rudolf Hanel, Dejan Stokic

Systems biology publications: 1

Stokic, D., Hanel, R. and Thurner, S., 2009, A fast and efficient gene-network reconstruction method from multiple over-expression experiments, *Bmc Bioinformatics* 10, 253.

7.1.15 Department of Vascular Biology & Thrombosis Research, Center for Physiology and Pharmacology/ Medical University of Vienna

Address: A-1090 Vienna,

<http://www.meduniVienna.ac.at/user/johannes.schmid/>

Systems biology relevant experts: Johannes Schmid (research group)

Systems biology projects: 'Transkriptionsfaktoren bei Entzündung und Krebs' (FWF)

7.1.16 Children's Cancer Research Institute (CCRI)/ St. Anna Kinderkrebsforschung Association

Address: 1090 Vienna,

http://www.ccri.at/science/index.php?gr_id=40&k_id=238

Systems biology relevant experts: Karla Maria Valdes Rodriguez

Systems biology projects: ASSET (FP7-HEALTH)

7.1.17 Institute for Medical Chemistry, Dpt. for Biomedical Sciences/ VU Vienna

Address: A-1210 Vienna,

http://www.vu-Vienna.ac.at/medchemie/content/index_ger.html

Systems biology relevant experts: Ingrid Miller (working group 'Peptid-, Protein- und Immunchemie')

Systems biology publications: 1

Bendixen, E., Danielsen, M., Hollung, K., Gianazza, E. and Miller, I., 2011, Farm animal proteomics – A review, *Journal of Proteomics* 74(3), 282-293.

7.1.18 Institute for Pharmacology and Toxicology, Dpt. for Biomedical Sciences/VU Vienna

Address: A-1210 Vienna,

http://vmutpp.vu-Vienna.ac.at/vuw/fodok/suche.orginheit_mitarbeiter?sprache_in=de&menue_id_in=203&id_in=118

Systems biology relevant experts: Katrin Staniek

Systems biology publications: 1

Ramzan, R., Staniek, K., Kadenbach, B. and Vogt, S., 2010, Mitochondrial respiration and membrane potential are regulated by the allosteric ATP-inhibition of cytochrome c oxidase, *Biochimica Et Biophysica Acta-Bioenergetics* 1797(8), 1672-1680.

7.1.19 Institute of Animal Breeding and Genetics, Dpt. for Biomedical Sciences/VU Vienna

Address: A-1210 Vienna, <http://www.vu-wien.ac.at/de/universitaet/departments/departments/tierzucht-und-genetik/>

Systems biology relevant experts: Mathias Müller

Systems biology projects:

Austrian Network for Functional Mouse Genomics II (GEN-AU, FFG)

7.1.20 dialog<>gentechnik

Address: A-1030 Vienna, Campus Vienna Biocenter, <http://www.dialog-gentechnik.at/>

Short description: dialog<>gentechnik was established by concerned scientists as 'Plattform Gentechnik & Wir' in 1997 in reaction to public controversies about agri-biotechnology and a resulting popular petition. The independent, non-profit association aims at providing substantiated, well-balanced information in a comprehensible way and enhancing exchange between scientists and lay people. It organises public events and contributes to the Vienna Open lab. It is funded exclusively by public sources.

Systems biology projects: EUSYSBIO (FP6-LIFESCIHEALTH)

7.2 Public research institutions: Lower Austria

7.2.1 Konrad Lorenz Institute (KLI)

Address: A-3422 Altenberg, <http://www.kli.ac.at/institute-a.html>

Systems biology relevant experts: Matthias Samwald

Short description: "Founded in 1990, the KLI is funded by a private trust and receives additional support from the Province of Lower Austria. The institute has close ties with many of the higher education institutions in Vienna and Lower Austria as well as with a number of international institutions with similar aims."⁷⁵

Systems biology publications: 1

Demir, E., Cary, M. P., Paley, S., Fukuda, K., Lemer, C., Vastrik, I., Wu, G. N., D'Eustachio, P., Schaefer, C., Luciano, J., Schacherer, F., Martinez-Flores, I., Hu, Z. J., Jimenez-Jacinto, V., Joshi-Tope, G., Kandasamy, K., Lopez-Fuentes, A. C., Mi, H. Y., Pichler, E., Rodchenkov, I., Splendiani, A., Tkachev, S., Zucker, J., Gopinath, G., Rajasimha, H., Ramakrishnan, R., Shah, I., Syed, M., Anwar, N., Babur, O., Blinov, M., Brauner, E., Corwin, D., Donaldson, S., Gibbons, F., Goldberg, R., Hornbeck, P., Luna, A., Murray-Rust, P., Neumann, E., Reubenacker, O., Samwald, M., van Iersel, M., Wimalaratne, S., Allen, K., Braun, B., Whirl-Carrillo, M., Cheung, K. H., Dahlquist, K., Finney, A., Gillespie, M., Glass, E., Gong, L., Haw, R., Honig, M., Hubaut, O., Kane, D., Krupa, S., Kutmon, M., Leonard, J., Marks, D., Merberg, D., Petri, V., Pico, A., Ravenscroft, D., Ren, L. Y., Shah, N., Sunshine, M., Tang, R., Whaley, R.,

⁷⁵ <http://www.kli.ac.at/institute/introduction>, accessed Feb. 4th, 2012.

Letovsky, S., Buetow, K. H., Rzhetsky, A., Schachter, V., Sobral, B. S., Dogrusoz, U., McWeeney, S., Aladjem, M., Birney, E., Collado-Vides, J., Goto, S., Hucka, M., Le Novère, N., Maltsev, N., Pandey, A., Thomas, P., Wingender, E., Karp, P. D., Sander, C. and Bader, G. D., 2010, The BioPAX community standard for pathway data sharing, *Nature Biotechnology* 28(9), 935-942.

7.3 Public research institutions: Upper Austria

7.3.1 Biophysics Institute/Johannes Kepler University Linz

Address: A-4040 Linz, <http://www.jku.at/biophysics/content>

Systems biology relevant experts: Gerhard J Schütz

Systems biology projects: LIPIDOMICNET (FP7-HEALTH)

7.3.2 Research Institute for Symbolic Computation/ Johannes Kepler University Linz

Address: A-4040 Linz, <http://www.risc.jku.at/>

Systems biology relevant experts: Franz Winkler

Systems biology publications: 1

Piazza, C., Antonioti, M., Mysore, V., Policriti, A., Winkler, F. and Mishra, B., 2005, Algorithmic algebraic model checking I: Challenges from systems biology, in: Etessami, K. and Rajamani, S. K. (Eds): *Computer Aided Verification* < Proceedings, 5-19.

7.4 Public research institutions: Styria

7.4.1 Department of Pharmaceutical Chemistry, Institute of Pharmaceutical Sciences/University of Graz

Address: A-8010 Graz, <http://www.uni-graz.at/ipcwww/>

Systems biology relevant experts: Andreas Kungl

Systems biology projects: Austrian Proteomics Platform II (GEN-AU, FFG); Austrian Proteomics Platform III (GEN-AU, FFG)

7.4.2 Institute of Molecular Biosciences/University of Graz

Address: A-8010 Vienna, <http://www.uni-graz.at/imbmwww.htm>

Systems biology relevant experts: Friedrich Spener, Klaus Natter, Christoph F. Kurat, Sepp D. Kohlwein, Gabriela Gogg-Fassolter; Frank Madeo

Systems biology relevant research groups:

Yeast Genetics and Molecular Biology Group/lipid metabolism
(Kohlwein, Kurat, Natter, Gogg-Fassolter)

Yeast Genetics and Molecular Biology Group/cell death (Madeo)

Systems biology projects:

APO-SYS (FP7-HEALTH); LIPIDOMICNET (FP7-HEALTH)

Systems biology publications: 2

Fahy, E., Subramaniam, S., Brown, H. A., Glass, C. K., Merrill, A. H., Murphy, R. C., Raetz, C. R. H., Russell, D. W., Seyama, Y., Shaw, W., Shimizu, T., Spener, F., van Meer, G., VanNieuwenhze, M. S., White, S. H., Witztum, J. L. and Dennis, E. A., 2005, A comprehensive classification system for lipids, *Journal of Lipid Research* 46(5), 839-861.

Zanghellini, J., Natter, K., Jungreuthmayer, C., Thalhammer, A., Kurat, C. F., Gogg-Fassolter, G., Kohlwein, S. D. and von Grunberg, H. H., 2008, Quantitative modeling of triacylglycerol homeostasis in yeast – metabolic requirement for lipolysis to promote membrane lipid synthesis and cellular growth, *Febs Journal* 275(22), 5552-5563.

7.4.3 Institute of Pathology, Center for Theoretical-Clinical Medicine I/Medical University of Graz

Address: 8036 Graz, <http://www.medunigraz.at/pathologie/I143>

Systems biology relevant experts: Kurt Zatloukal⁷⁶

Systems biology relevant research groups:

Research laboratory for molecular pathology, experimental cell biology and oncology

Systems biology projects:

ESGI (FP7-INFRASTRUCTURES);

ESBIC-D (FP6-LIFESCIHEALTH); livSYSiPS (ERASysBio)

7.4.4 Division of Endocrinology and Metabolism, Internal Medicine I/Medical University of Graz

Address: A-8036 Graz, http://forschung.meduni-graz.at/fodok/suchen.orginheit_uebersicht?sprache_in=de&menue_id_in=201&id_in=4120, https://online.medunigraz.at/mug_online/webnav.navigate_to?corg=15207&cperson_nr=51861

Systems biology relevant experts: Thomas Wascher

Systems biology publications: 1

Maahs, D. M., Siwy, J., Argiles, A., Cerna, M., Delles, C., Dominiczak, A. F., Gayraud, N., Iphofer, A., Jansch, L., Jerums, G., Medek, K., Mischak, H., Navis, G. J., Roob, J. M., Rossing, K., Rossing, P., Rychlik, I., Schiffer, E., Schmieder, R. E., Wascher, T. C., Winklhofer-Roob, B. M., Zimmerli, L. U., Zurbig, P. and Snell-Bergeon, J. K., 2010, Urinary Collagen Fragments Are Significantly Altered in Diabetes: A Link to Pathophysiology, *Plos One* 5(9), e13051.

⁷⁶ Kurt Zatloukal also took part in many preparatory EU panels on systems biology research funding and coordination as an Austrian systems biology expert.

7.5 Public research institutions: Tyrol

7.5.1 Department of Pharmacognosy, Institute of Pharmacy/ University of Innsbruck

Address: A-6020 Innsbruck,
<http://www.uibk.ac.at/pharmazie/pharmakognosie/>

Systems biology relevant experts: Christoph Seger, Sonja Sturm

Systems biology publications: 2

Holmes, E., Tang, H. R., Wang, Y. L. and Seger, C., 2006, The assessment of plant metabolite profiles by NMR-based methodologies, *Planta Medica* 72(9), 771-785.

Seger, C. and Sturm, S., 2007, Analytical aspects of plant metabolite profiling platforms: Current standings and future aims, *Journal of Proteome Research* 6(2), 480-497.

7.5.2 Institute of Analytical Chemistry and Radiochemistry/ University of Innsbruck

Also: *Horváth Laboratory of Bioseparation Sciences*, with its main office at the Institute of Analytical Chemistry and Radiochemistry and a first full subsidiary at the Department of Medical Chemistry in University of Debrecen (Hungary). Günther Bonn and Barry L. Karger function as chairmen of the two advisory boards, András Guttman as head of the laboratory (<http://www.hlbs.org/>, accessed 2.4.2012).

Address: A-6020 Innsbruck, <http://www.uibk.ac.at/acrc/>

Systems biology relevant experts:
Günther Bonn, Christian Huck, András Guttman

Systems biology projects:
COBRED (FP6-LIFESCIHEALTH);
Austrian Proteomics Platform II (GEN-AU, FFG);
Austrian Proteomics Platform III (GEN-AU, FFG)

Systems biology publications: 2

Csanky, E., Olivova, P., Rajnavolgyi, E., Hempel, W., Tardieu, N., Katalin, E. T., Jullien, A., Malderez-Bloes, C., Kuras, M., Duval, M. X., Nagy, L., Scholtz, B., Hancock, W., Karger, B., Guttman, A. and Takacs, L., 2007, Monoclonal antibody proteomics: Discovery and prevalidation of chronic obstructive pulmonary disease biomarkers in a single step, *Electrophoresis* 28(23), 4401-4406.

Szilagyi, A., Bonn, G. K. and Guttman, A., 2007, Capillary gel electrophoresis analysis of G-quartet forming oligonucleotides used in DNA-protein interaction studies, *Journal of Chromatography A* 1161(1-2), 15-21.

7.5.3 Division of Bioinformatics, Biocenter/ Innsbruck Medical University

Address: A-6020 Innsbruck, Website: <http://icbi.at/index.html>

Systems biology relevant experts: Zlatko Trajanoski, Hubert Hackl, Gernot Stocker, Pornpimol Charoentong, Stephan Pabinger

Close links to:

Institute for Genomics and Bioinformatics, Graz University of Technology
Oncotyrol AREA5: Bioinformatics and Systems Biology
Bioinformatics Integration Network I – III

Systems biology projects:

Bioinformatics Integration Network III (GEN-AU, FFG)

Systems biology publications: 2

Hackl, H., Stocker, G., Charoentong, P., Mlecnik, B., Bindea, G., Galon, J. and Trajanoski, Z., 2010, Information technology solutions for integration of biomolecular and clinical data in the identification of new cancer biomarkers and targets for therapy, *Pharmacology & Therapeutics* 128(3), 488-498.

Pabinger, S., Rader, R., Agren, R., Nielsen, J. and Trajanoski, Z., 2011, MEMOSys: Bioinformatics platform for genome-scale metabolic models, *Bmc Systems Biology* 5, 20.

7.5.4 Division of Cell Biology, Biocenter/ Innsbruck Medical University

Address: A-6020 Innsbruck, <http://biocenter.i-med.ac.at/index.php/cellbiohome>, <http://www.i-med.ac.at/cellbio/>

Systems biology relevant experts: Lukas A. Huber

Systems biology projects:

Austrian Proteomics Platform III (GEN-AU, FFG)

Systems biology publications: 1

Morandell, S., Stasyk, T., Skvortsov, S., Ascher, S. and Huber, L. A., 2008, Quantitative proteomics and phosphoproteomics reveal novel insights into complexity and dynamics of the EGFR signaling network, *Proteomics* 8(21), 4383-4401.

7.5.5 Division of Physiology, Department of Physiology and Medical Physics/Innsbruck Medical University

Address: A-6020 Innsbruck, <http://physiologie.i-med.ac.at/>

Systems biology relevant experts: Paul Jennings

Systems biology projects:

CARCINOGENOMICS (FP6-LIFESCIHEALTH)

7.5.6 Division of Human Genetics, Department of Medical Genetics, Molecular and Clinical Pharmacology/ Innsbruck Medical University

Address: A- 6020 Innsbruck, <http://www.sfb021.at/baier/>

Systems biology relevant experts: Gottfried Baier

Systems biology projects: SYBILLA (FP7-HEALTH)

7.5.7 Urology, Department Operative Medizin/ Innsbruck Medical University

Address: A- 6020 Innsbruck, <http://www.uro-innsbruck.at/>

Systems biology relevant experts: Helmut Klocker

Systems biology projects: CANCURE (FP6-MOBILITY)

7.5.8 Cardiac Surgery, Department Operative Medizin/ Innsbruck Medical University

Address: A-6020 Innsbruck, https://inside.i-med.ac.at/online/visitenkarte.show_vcard?pPersonenId=FA341A4D9C70F236&pPersonenGruppe=3

Systems biology relevant experts: Andrej Kuznetsov

Systems biology publications: 4

Guzun, R., Timohhina, N., Tepp, K., Gonzalez-Granillo, M., Shevchuk, I., Chekulayev, V., Kuznetsov, A. V., Kaambre, T. and Saks, V. A., 2011, Systems bioenergetics of creatine kinase networks: physiological roles of creatine and phosphocreatine in regulation of cardiac cell function, *Amino Acids* 40(5), 1333-1348.

Saks, V., Guzun, R., Timohhina, N., Tepp, K., Varikmaa, M., Monge, C., Beraud, N., Kaambre, T., Kuznetsov, A., Kadaja, L., Eimre, M. and Seppet, E., 2010, Structure-function relationships in feedback regulation of energy fluxes in vivo in health and disease: Mitochondrial Interactosome, *Biochimica Et Biophysica Acta-Bioenergetics* 1797(6-7), 678-697.

Guzun, R., Karu-Varikmaa, M., Gonzalez-Granillo, M., Kuznetsov, A. V., Michel, L., Cottet-Rousselle, C., Saaremaa, M., Kaambre, T., Metsis, M., Grimm, M., Auffray, C. and Saks, V., 2011, Mitochondria-cytoskeleton interaction: Distribution of beta-tubulins in cardiomyocytes and HL-1 cells, *Biochimica Et Biophysica Acta-Bioenergetics* 1807(4), 458-469 .

Saks, V., Guzun, R., Timohhina, N., Tepp, K., Varikmaa, M., Monge, C., Beraud, N., Kaambre, T., Kuznetsov, A., Kadaja, L., Margus, E. and Seppet, E., 2010, Systems biology and bioenergetics: Structure-function relationships in feedback regulation of energy fluxes in vivo Mitochondrial interactosome, *Biochimica Et Biophysica Acta-Bioenergetics* 1797, 138-138.

7.5.9 Nephrology and Hypertension, Internal Medicine IV/ Innsbruck Medical University

Address: A-6020 Innsbruck, <http://www.nephrologie-innsbruck.at/index.php#>, <http://www.microarray.at/index.php>

Systems biology relevant experts: Gert Mayer, Susanna Eder, Dorothea Heininger, Michael Rudnicki, Susie-Jane Noppert, J. Enrich

Systems biology relevant research groups:
Functional Genomics and Biomarker Research group

Systems biology projects: SYSKID (FP7-HEALTH)

Systems biology publications: 4

Rudnicki, M., Perco, P., Enrich, J., Eder, S., Heininger, D., Bernthaler, A., Wiesinger, M., Sarkozi, R., Noppert, S. J., Schramek, H., Mayer, B., Oberbauer, R. and Mayer, G., 2009, Hypoxia response and VEGF-A expression in human proximal tubular epithelial cells in stable and progressive renal disease, *Laboratory Investigation* 89(3), 337-346.

Perco, P., Rapberger, R., Siehs, C., Lukas, A., Oberbauer, R., Mayer, G. and Mayer, B., 2006, Transforming omics data into context: Bioinformatics on genomics and proteomics raw data, *Electrophoresis* 27(13), 2659-2675.

Perco, P., Muhlberger, I., Mayer, G., Oberbauer, R., Lukas, A. and Mayer, B., 2010, Linking transcriptomic and proteomic data on the level of protein interaction networks, *Electrophoresis* 31(11), 1780-1789.

Perco, P., Wilflingseder, J., Bernthaler, A., Wiesinger, M., Rudnicki, M., Wimmer, B., Mayer, B. and Oberbauer, R., 2008, Biomarker candidates for cardiovascular disease and bone metabolism disorders in chronic kidney disease: a systems biology perspective, *Journal of Cellular and Molecular Medicine* 12(4), 1177-1187. Institute for Biomedical Aging Research (IBA)/ Austrian Academy of Sciences.

7.5.10 Institute for Biomedical Aging Research (IBA)/ Austrian Academy of Sciences

Address: A-6020 Innsbruck, <http://www.iba.oeaw.ac.at/index.php?id=9>

Systems biology relevant experts:
Beatrix Grubeck-Loebenstein, Pidder Jansen-Dürr, Hermann Unterluggauer

Systems biology relevant research groups:
The Grubeck-Loebenstein Group (Immunology)
The Jansen-Dürr Group (Molecular and Cell Biology)

Systems biology projects: ADITEC (FP7-Health)

Systems biology publications: 1

Groebe, K., Klemm-Manns, M., Schwall, G. P., Hubenthal, H., Unterluggauer, H., Jansen-Dürr, P., Tanguay, R. M., Morrow, G. and Schrattenholz, A., 2010, Age-dependent posttranslational modifications of voltage-dependent anion channel 1, *Experimental Gerontology* 45(7-8), 632-637.

7.6 Public-private partnership institutions and companies

7.6.1 Institute of Molecular Biotechnology GmbH (IMBA)/ Austrian Academy of Sciences

Address: A-1030 Vienna, Campus Vienna Biocenter,
<http://www.imba.oeaw.ac.at/>

Short description: IMBA is a joint initiative of the Austrian Academy of Sciences and Boehringer Ingelheim; founded in 1999, the operative work at IMBA starts in 2003 and its new building 'Life Sciences Center Vienna' opened in 2006. It holds a Shared-Services agreement with IMP.

Systems biology relevant researchers: Josef Penninger

Systems biology projects:

Austrian Network for Functional Mouse Genomics II (GEN-AU, FFG)

Systems biology publications: 2

Kocher, T., Pichler, P., Swart, R. and Mechtler, K., 2011, Quality control in LC-MS/MS, *Proteomics* 11(6), 1026-1030

Leibbrandt, A. and Penninger, J. M., 2009, ESCI award lecture: from a little mouse to rationale medicine for bone loss, *European Journal of Clinical Investigation* 39(10), 842-850.

7.6.2 Ludwig Boltzmann Institute for Cancer Research (LBI-CR)

Address: A-1090 Vienna, <http://lbicr.lbg.ac.at/en>

Short description: "The initiative to found a new Ludwig Boltzmann Institute for Cancer Research (LBI-CR) was started in 2004 and successfully accomplished in September 2005. Three scientists from the Institute of molecular Pathology (IMP), two scientists from the Medical University Vienna and a scientist from the Biocenter Basel formed a team in order to break new ground in cancer research. (...) The application was supported by 5 partner institutions (the Medical University Vienna, the Institute of Molecular Pathology (IMP), the Research Institute of the St. Anna Kinderspital and the biotech companies TissueGnostics GmbH and Cell Danube AG) – and was accepted in December 2004 as one out of six new Ludwig Boltzmann Institutes."

Systems biology relevant experts: Robert Eferl, Emilio Casanova

Systems biology projects:

Austrian Network for Functional Mouse Genomics II (GEN-AU, FFG)

7.6.3 Christian Doppler Laboratory for Allergy Research/ University of Vienna

Address: A-1090 Vienna,
<http://www.meduniVienna.ac.at/allergy-research-christian-doppler/>

Systems biology relevant experts: Rudolf Valenta

Systems biology projects: MEDALL (FP7-HEALTH)

7.6.4 Christian Doppler Laboratory for Molecular Recognition Materials/University of Vienna

Auch: Department of Analytical Chemistry and Food Chemistry, Institute of Analytical Chemistry, University of Vienna

Short description: “The Christian Doppler (CD) Laboratory for Molecular Recognition Materials was founded at the beginning of 2002 at the Department of Analytical Chemistry and Food Chemistry and is headed by Assoc. Prof. Dr. Michael Lämmerhofer and Prof. Dr. Wolfgang Lindner. It is financed to 50% by the Austrian government (through the Christian-Doppler-Society), with the second half of its budget being provided by the involved companies. Industrial partners are the Swedish pharmaceutical company AstraZeneca, the German chemical-pharmaceutical company Merck KGaA, the pharmaceutical company Fresenius Kabi Austria and the Austrian start-up company piCHEM, which is active in the area of peptide chemistry.”

Address: A-1090 Vienna, <http://www.univie.ac.at/cdlformrm/index.html>

Systems biology relevant experts: Beatrix Preinerstorfer, Simone Schiesel, Michael Lämmerhofer, Wolfgang Lindner

Systems biology projects: Austrian Proteomics Platform II (GEN-AU, FFG); Austrian Proteomics Platform III (GEN-AU, FFG)

Systems biology publications: 1

Preinerstorfer, B., Schiesel, S., Lämmerhofer, M. L. and Lindner, W., 2010, Metabolic profiling of intracellular metabolites in fermentation broths from beta-lactam antibiotics production by liquid chromatography-tandem mass spectrometry methods, *Journal of Chromatography A* 1217(3), 312-328.

7.6.5 Christian Doppler Laboratory for Proteome Analysis/University of Vienna

Address: A-1030 Vienna, Vienna Biocenter, http://cdl-proteome.at/?Christian_Doppler_Laboratory

Systems biology relevant experts: Peter Pichler

Systems biology publications: 1

Kocher, T., Pichler, P., Swart, R. and Mechtler, K., 2011, Quality control in LC-MS/MS, *Proteomics* 11(6), 1026-1030.

7.6.6 Christian Doppler Laboratory for Genomics and Bioinformatics/Technical University Graz

Address: A-8010 Graz, <http://genome.tugraz.at/contact.shtml>

Systems biology relevant experts: R. Rader, S. Pabinger, Zlatko Trajanoski

Systems biology publications: 1

Pabinger, S., Rader, R., Agren, R., Nielsen, J. and Trajanoski, Z., 2011, MEMOSys: Bioinformatics platform for genome-scale metabolic models, *Bmc Systems Biology* 5, 20.

7.6.7 Biomarker Design Forschung GmbH (BDF)

Address: A-1210 Vienna, <http://www.biomarker-design.at/>

Short description: “Biomarker Design Forschung GmbH (BDF) is a biotech R&D company incorporated in April 2009. The staff includes all the employees of the research department of Biomedica Medizinprodukte GmbH & Co Kg (Biomedica), who have successfully developed new innovative ELISA systems for clinical research on diseases of the cardiovascular system and bone metabolism. We focus our work on finding new innovative biomarkers by cooperation with basic research at Universities or with small and medium Biotech companies and our own internal research efforts.”

Systems biology projects: SYSKID (FP7-HEALTH)

7.6.8 Biomodels Austria (Universitäres Zentrum für Biomodelle GmbH)

Address: A-1210 Vienna, <http://www.biomodels.at/>

Short description: Established in 2002, the former ‘Österreichisches Zentrum für Biomodelle und Transgenetik’ (ÖZBT) was a joint venture of the Veterinary University of Vienna, the Medical University of Vienna and the Department for Agrobiotechnology (IFA) Tulln. In 2005, it was transformed into a [limited liability company](#) (GmbH) and renamed in 2006 as ‘Biomodels Austria, Universitäres Zentrum für Biomodelle GmbH’.

Systems biology projects:

Austrian Network for Functional Mouse Genomics II (GEN-AU, FFG)

7.6.9 Biomay AG

Address: A-1090 Vienna, <http://www.biomay.com/>

Short description: “The Biomay Produktions- und Handels-Aktiengesellschaft, founded 17 years ago by Mag. Mayrhofer, today claims an important place among the young gene technology companies which are at the forefront of research in the pharmaceutical industry, thereby providing effective treatment possibilities for various diseases.”⁷⁷ BIOMAY holds close contacts to four Christian-Doppler-Laboratories based at the Medical University of Vienna and the University of Salzburg (*Allergy Research, Immunomodulation, Allergen Chips, Allergy Diagnosis and Therapy*), representing an Austrian allergy research cluster.

Systems biology relevant experts: Ursula Baumgartner

Systems biology projects: MEDALL (FP7-HEALTH)

Systems biology publications: 1

Bousquet, J., Anto, J., Auffray, C., Akdis, M., Cambon-Thomsen, A., Keil, T., Haahtela, T., Lambrecht, B. N., Postma, D. S., Sunyer, J., Valenta, R., Akdis, C. A., Annesi-Maesano, I., Arno, A., Bachert, C., Ballester, F., Basagana, X., Baumgartner, U., Bindslev-Jensen, C., Brunekreef, B., Carlsen, K. H., Chatzi, L., Cramer, R., Eveno, E., Forastiere, F., Garcia-Aymerich, J., Guerra, S., Hammad, H., Heinrich, J., Hirsch, D., Jacquemin, B., Kauffmann, F., Kerkhof,

⁷⁷ <http://www.biotechindustry.at/EN/biotechindustry.at/Members/Biomay%20AG/Biomay+AG.aspx>, accessed Feb. 4th, 2012.

M., Kogevinas, M., Koppelman, G. H., Kowalski, M. L., Lau, S., Lodrup-Carlsen, K. C., Lopez-Botet, M., Lotvall, J., Lupinek, C., Maier, D., Makela, M. J., Martinez, F. D., Mestres, J., Momas, I., Nawijn, M. C., Neubauer, A., Oddie, S., Palkonen, S., Pin, I., Pison, C., Rance, F., Reitamo, S., Rial-Sebbag, E., Salapatas, M., Siroux, V., Smaghe, D., Torrent, M., Toskala, E., van Cauwenberge, P., van Oosterhout, A. J. M., Varraso, R., von Hertzen, L., Wickman, M., Wijmenga, C., Worm, M., Wright, J. and Zuberbier, T., 2011, MeDALL (Mechanisms of the Development of ALLergy): an integrated approach from phenotypes to systems medicine, *Allergy* 66(5), 596-604.

7.6.10 Intercell AG

Address: 1030 Vienna, <http://www.intercell.com/>

Short description: The Intercell AG was established as a Vienna BioCenter (University of Vienna) spin-off in 1998 by Alexander von Gabain (CEO), Max Birnstiel and three other high-ranking, international scientists, with a focus on the biotechnological development and production of vaccines against infectious diseases. It was financed by venture capital and funding by the FFF and WWTF. In 2000, it was transformed into a company, going public in 2005. In 2010, Novartis held a share of 15.9 % (Resch and Hofer 2010: 263-265).

Systems biology projects:

ADITEC (FP7-HEALTH); PNEUMOPATH (FP7-HEALTH)

7.6.11 TissueGnostics GmbH

Address: A-1020 Vienna, <http://www.tissuegnostics.com/EN/home.php>

Short description: established in 2003 by Katja Österreicher, Georg Steiner and Rupert Ecker with the aid of a dozen of development partners (Medical University Vienna, Memorial Sloan-Kettering Cancer Center New York, Ludwig Boltzmann Institute for Cancer Research, Vienna; Fred Hutchinson Cancer Center, Seattle; Brigham and Women's Hospital, Boston; etc.), it purchased TissueGnostics Romania and founded TissueGnostics USA Inc. only four years later. For 2010, the company reported active sales in more than 30 countries. Academic partners include the *Ludwig Boltzmann Institute for Cancer Research (LBI-CR)* Vienna, the *Department of Pathophysiology and Allergy Research* and the *Department of Urology* at the Medical University of Vienna, the *Urology Department* at Innsbruck Medical University and *Onco-tyrol*.

Systems biology relevant experts: R.C. Ecker

Systems biology publications: 1

Ecker, R. C. and Tarnok, A., 2005, Cytomics: An entry to biomedical cell systems biology – Cytomics goes 3D: Toward tissomics, *Cytometry Part A* 65A(1), 1-3

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- Brüninghaus, A. and Kastenhofer, K., 2012, Governance eines neuen Forschungsfeldes: Diskurse zur Systembiologie in Politik und Öffentlichkeit in Deutschland und Österreich, manuscript, 55pp.
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Annexes

A.I Systems biology projects funded within the EU Sixth and Seventh Framework Programmes

An ‘all fields search’ for ‘systems biology’ within the database for all FP 6 and FP 7 projects⁷⁸ results in the following lists of funded projects (details for these projects can be found in the same CORDIS database):

A.I.1 Systems biology projects funded within the EU Sixth Seventh Framework Programmes

- (1) A bioinformatics and systems biology approach for the functional analysis of a growth-regulating MAP kinase pathway in Arabidopsis, ARA-MKK-D
- (2) A combined Cryo Electron Microscopy and mass Spectrometry approach for the structural and functional characterization of the URI-complex, CRYO-EM URI-COMPLEX
- (3) A European model for bioinformatics research and community education, EMBRACE
- (4) A SNP and haplotype map for the rat, STAR
- (5) An integrative approach to cellular signalling and control processes: Bringing computational biology to the bench, COMBIO
- (6) AnEUploidy: understanding the importance of gene dosage imbalance in human health using genetics, functional genomics and systems biology, ANEUPLOIDY
- (7) Arabidopsis growth network integrating OMICS technologies, AGRON-OMICS
- (8) ASSESSMENT OF THE EUROPEAN TERRESTRIAL CARBON BALANCE, CARBOEUROPE-IP
- (9) Bacterial gene networks and the cell cycle, GENES AND GROWTH
- (10) Biological computation built on cell communication systems; CELLCOMPUT
- (11) Biosimulation – A New Tool in Drug Development, BIOSIM
- (12) CANCER CURE Early stage research training, CANCURE
- (13) Cellulose architecture systems biology for plant innovation creation; CASPIC
- (14) Chromosome substitution strains: a powerful tool to study the stress response in mouse, CSS-OMICS
- (15) Colon and breast cancer diagnostics, COBRED

⁷⁸ <http://cordis.europa.eu/search/index.cfm?fuseaction=proj.advSearch>, accessed March 13th, 2012.

- (16) Computational modeling of cell cycle activity and leaf development in *Arabidopsis thaliana*, LEAFMORPHOSIM
- (17) Computational systems biology of cell signalling, COSBICS
- (18) Corn Leaf Acclimation to Water Stress: Towards uncovering the molecular network that controls cell division and expansion in the growth zone with an emphasis on the role of Reactive Oxygen Species, CLAWS
- (19) Dedicated integration and modelling of novel data and prior knowledge to enable systems biology, DIAMONDS
- (20) Defects in the tricarboxylic acid (KREBS) cycle genes in tumorigenesis, TCAC IN CANCER
- (21) Design and Engineering of gene networks to respond to and correct alterations in signal transduction pathways, NETSENSOR
- (22) Development of a high throughput genomics-based test for assessing genotoxic and carcinogenic properties of chemical compounds in vitro; CARCINOGENOMICS
- (23) Development of metabolomics and fluxomics methods for metabolic drug target and toxicity elucidation using yeast, CHEMOFLUXOME
- (24) Dietary polyphenols, gut microbes and human health: A systems biology approach; GUTSYSTEM
- (25) DNA damage response and repair mechanisms, DNA REPAIR
- (26) Dynamics and complexity in synthetic protein networks, SYNPLEXITY
- (27) Empowering the micro-array-based European research area to take a lead in development and exploitation, EMERALD
- (28) ENFIN – an experimental network for functional integration, ENFIN
- (29) Engineered modular bacterial hydrogen photo-production of hydrogen; BIOMODULARH2
- (30) Entrainment of the circadian clock, EUCLOCK
- (31) European Conference on Mathematical and Theoretical Biology 2005; ECMTB05
- (32) European systems biology initiative for combating complex diseases, ESBIC-D
- (33) Evolution of the Protein-Interaction Networks: the SH3 network in Yeast, PENELOPE
- (34) From gene regulatory networks to drug prediction, NET2DRUG
- (35) Function and regulation of the type 2 vasopressin receptor and 'V2R' in body fluid homeostasis, AVP-V2R
- (36) Functional analysis of plant metacaspases type II, PLANT METACASPASES
- (37) Generating an integrative plant science, GIPS
- (38) HYperspectral REMote Sensing in Europe – specific Support Actions; HYRESSA
- (39) IMPACTS AND RISKS FROM ANTHROPOGENIC DISTURBANCES ON SOILS, CARBON DYNAMICS AND VEGETATION IN PODZOLIC ECOSYSTEMS, OMRISK

- (40) IMPROVING THE YIELD STABILITY OF DURUM WHEAT UNDER MEDITERRANEAN CONDITIONS, OPTIWHEAT
- (41) Interdisciplinary training in systems biology, SYSTEMS BIOLOGY
- (42) Investigation of the transcriptional regulation of the antioxidant network in bundle sheath cells of Arabidopsis using a novel immunocapture technique for bundle sheath specific polysomes, ANTIOXARAB
- (43) Metabolomics of salicylate induced plants, MESAIP
- (44) Million frame per second, time-correlated single photon camera; MEGAFRAME
- (45) Modeling signaling pathways in cartilage degeneration, MOSPAIC
- (46) Novel computational and informatics approaches for the quantitative studies of proteins, COMPROT
- (47) Novel molecular tools for the analysis of the cell membrane proteome and interactome, MOLTOOL/INTERACTOM
- (48) Reconstructing regulatory networks from high-throughput post – genomic data, REGULOMICS
- (49) Scalable modelling and analysis techniques to study emergent cell behaviour – understanding the E. coli stress response, EC-MOAN
- (50) Shaping new directions in Mathematics for Science and Society, MATHFSS
- (51) Simulation modelling of the MAP kinase pathway, SIMAP
- (52) Synthesis and nanotechnological application of tethered silicates, SANTS
- (53) Synthetic biomimetic nanoengines: A modular platform for engineering of nanomechanical actuator building blocks, NANOMOT
- (54) Systematic functional analysis of intracellular parasitism as a model of genomes conflict, SYSCO
- (55) Systems biology for medical applications, SYSBIOMED
- (56) Systems Biology of Glucose Repression in Yeast, SYBGRY
- (57) Systems biology of nuclear receptors: A nutrigenomics approach to aging-related diseases, NUCSYS
- (58) Systems biology of RNA metabolism in yeast, RIBOSYS
- (59) SYSTEMS BIOLOGY OF STEM CELL FUNCTION IN ARABIDOPSIS THALIANA, SY-STEM
- (60) Systems biology of the AMP-activated protein kinase pathway, AMPKIN
- (61) Systems biology strategies and metabolome engineering for the enhanced production of recombinant proteins in streptomyces, STREPTOMICS
- (62) Systems Sciences; ERASYSBIO
- (63) System-wide analysis and modelling of protein modification, SYSPROT
- (64) Temporal Genomics for tailored chronotherapeutics, TEMPO
- (65) The Take-off of European Systems Biology, EUSYSBIO
- (66) The technologies of biological membranes, MEMPROT
- (67) Towards an understanding of dynamic transcriptional regulation at global scale in bacteria: a systems biology approach, BASYSBIO

- (68) Towards European Neuromal Cell Simulation: a European consortium to integrate the scientific activities for the creation of a European Alliance devoted to the complete in-silico model of Neuronal Cell, SYMBIONIC
- (69) Training in plant systems biology, PLANT SYSTEMS BIOLOG
- (70) Wnt signalling and adipose tissue plasticity, WNT ADIPOSE TISSUE
- (71) Workshop on 'Systems biology of DNA-damage-induced stress responses', EU-US WORKSHOP
- (72) Yeast Systems Biology Network, YSBN

A.1.2 Systems biology projects funded within the EU Seventh Framework Programmes

- (1) 4C technology: uncovering the multi-dimensional structure of the genome, 4C
- (2) A combined experimental and computational approach for quantitative and mechanistic understanding of transcriptional regulation, TRANSCRIPTION_REG
- (3) A combined post-genomics, biochemical and biophysical investigation to model the systems biology of embryo cell expansion and seed germination in *Arabidopsis thaliana*, EXPANSION
- (4) A comparative genomic analysis into the origin of metazoan multicellularity, MULTICELLGENOME
- (5) A comprehensive dissection of pneumococcal-host interactions, PNEUMOPATH
- (6) A Computational Systems Biology Approach to Reveal the Molecular Basis of Complex Diseases, EYLCOMPDISSYSBIO
- (7) A cross-species neurogenomics approach to anxiety, GENANX
- (8) A novel mode of TGF-beta signalling through Smad1/Smad5 phosphorylation: mechanism and functional role in cancer, SMAD1/5 AND CANCER
- (9) a Study of the Epigenetic Alterations that Result in Cardiac Hypertrophy, SEARCH
- (10) A system view on the differential activities of human type I interferons, IFNACTION
- (11) A systems approach to defining membrane protein networks and applications, TRANSYS
- (12) A Systems Biology Approach to controlling Nematode Infections of Livestock ,NEMATODESYSTEMHEALTH
- (13) A Systems Biology approach to disclose auxin synthesis in plants, SYSBIOAUX
- (14) A systems biology approach to dissect cilia function and its disruption in human genetic disease ,SYSCILIA
- (15) A systems biology approach to elucidate the yeast metabolic network, MRM-YEAST METABOLISM

- (16) A systems BIOlogy Study to TAilored Treatment in Chronic Heart Failure, BIOSTAT-CHF
- (17) Accelerating the transition to a toxicity pathway-based paradigm for chemical safety assessment through internationally coordinated research and technology development, AXLR8
- (18) Actin-membrane interaction in biomimetic and living cellular systems studied with a novel, high precision optical method, BIOMIMETIC-CORTEX
- (19) Advanced bioanalytical technologies for systems biology studies, ADVANCED BIOANALYSIS
- (20) Advanced Immunization Technologies, ADITEC
- (21) Airway Disease PREdicting Outcomes through Patient Specific Computational Modelling, AIRPROM
- (22) An integrated study on three novel regulatory hubs in megakaryocytes and platelets, discovered as risk genes for myocardial infarction by a genome-wide association and platelet systems biology study, NETSIM
- (23) Apoptosis systems biology applied to cancer and AIDS. An integrated approach of experimental biology, data mining, mathematical modelling, biostatistics, systems engineering and molecular medicine, APO-SYS
- (24) Assembly and maintenance of a co-regulated chromosomal compartment, ACCOMPLI
- (25) ASSET: Analysing and Striking the Sensitivities of Embryonal Tumours, ASSET
- (26) BIO knowLEDGe Extractor and Modeller for Protein Production, BIOLEDGE
- (27) Biology of liver and pancreatic development and disease, BOLD
- (28) Bioproduction of pharmaceutically important iridoids: systems biology based approach, SYSBIOPRO
- (29) Breaking the code of RNA sequence-structure-function relationships: New strategies and tools for modelling and engineering of RNA and RNA-protein complexes, RNA+P=123D
- (30) Cancerbiome: Characterization of the cancer-associated microbiome, CANCERBIOME
- (31) Canine models of human psychiatric disease: identifying novel anxiety genes with the help of man's best friend, DOGPSYCH
- (32) Cell Growth and Size Homeostasis in Proliferating Mammalian Cells, CELLCYCLEGROWTHSIZE
- (33) Characterization and modelling of dietary effects mediated by gut microbiota on lipid metabolism, ETHERPATHS
- (34) Characterization and quantitative modeling of DNA mismatch repair and its role in the maintenance of genomic stability and cancer avoidance, MISMATCH2MODEL
- (35) Charting the landscape of brain development by large-scale single-cell transcriptomics and phylogenetic lineage reconstruction, BRAINCELL
- (36) Chemogenomic profiling of drug-protein binding by shape, enthalpy/entropy and interaction kinetics, DRUGPROFILBIND

- (37) Chromatin and transcription in ES cells: from single cells to genome wide views, EXPRES
- (38) Cis-regulatory logic of the transcriptional control in neural stem cells, CISSTEM
- (39) Communication Motifs: Principles of bacterial communication in non-genetically diversified populations, COMMOTS
- (40) Comparative Genomics and Next Generation Sequencing, COGANGS
- (41) Compartmentalization and dynamics of nuclear functions, CDNF
- (42) Connecting the animal genome, gastrointestinal microbiomes and nutrition to improve digestion efficiency and the environmental impacts of ruminant livestock production, RUMINOMICS
- (43) Conservation and divergence of tissue-specific transcriptional regulation, CONSERVREGCIRCUITRY
- (44) Conserved Non-Coding Sequences; function, variability and phenotypic consequences, HUCNC
- (45) Control of light use efficiency in plants and algae – from light to harvest, HARVEST
- (46) Controlling stochastic gene expression during development and stem cell differentiation, GENENOISECONTROL
- (47) Coordination of oxidative stress signalling with forkhead-regulated transcription during the fission yeast cell cycle, OXICELLCYCLE
- (48) Coordination of resources for conditional expression of mutated mouse alleles, CREATE
- (49) Decoding genetic switches in T helper cell differentiation, THSWITCH
- (50) Decoding the complexity of quantitative natural variation in *Arabidopsis thaliana*, DECODE
- (51) Decomposition and Discovery of Complex Networks, DEDINET
- (52) Derived and Ancestral RNAs: Comparative Genomics and Evolution of ncRNAs, DARCGENS
- (53) Design principles and controllability of protein circuits, DEPICT
- (54) Detection and interpretation of de novo mutations and structural genomic variations in mental retardation, DENOVO
- (55) Determinants of mammalian transcription start site selection and core promoter usage, DTSSCP
- (56) Determining the roles of the nuclear periphery in mammalian genome function, FUNCTIONALEDGE
- (57) Developing maximum-resolution genotype-phenotype maps using whole-genome polymorphism data, MAXMAP
- (58) Developing single cell technologies for systems biology, ISOLATE
- (59) Development of microRNA Medicines for Cardiac Metabolic Diseases; A Targeted European Exchange Programme, CARDIOMIR
- (60) Development of novel treatment strategies based on knowledge of cellular dysfunction in diabetes, BETABAT
- (61) Development of systems for high content screening of live cells, HICONTCELLSCREEN

- (62) Developmental and genetic analysis of DNA double-strand break repair, DSBREPAIR
- (63) Developmental effects of environment on reproductive health, DEER
- (64) DISSECTING GENETIC DEPENDENCIES IN CANCER, FUNCTIONAL GENOMICS
- (65) Dissecting the transcriptional mechanisms controlling growth during normal development and cancer, GROWTHCONTROL
- (66) Dissection of environmentally-mediated epigenetic silencing, ENVGENE
- (67) DNA Repair in Individual BACterial Cells, DRIBAC
- (68) Doxorubicin-induced impairment of metabolic and stress signaling: A culprit of cardiotoxic action of the drug?, ANTHRPLUS
- (69) Dynamic Interplay between Eukaryotic Chromosomes: Impact on Genome Stability, DICIG
- (70) Dynamic protein-DNA interactomes and circadian transcription regulatory networks in mammals, DYNACLOCK
- (71) Dynamics and stability of covalent protein modifications, PROTMOD
- (72) Dynamics of local transcriptomes and proteomes in neurons, NEURONAL DYNAMICS
- (73) e-Laboratory for interdisciplinary collaborative research in data mining and data-intensive sciences, E-LICO
- (74) Elucidation of the molecular and functional basis of disease phenotypes in the rat model, ELABORATE
- (75) Engineering zinc fingers to target cancer hub genes, ZINC-HUBS
- (76) Enhancing access and services to east European users towards an efficient and coordinated panEuropean pool of NMR capacities to enable global collaborative research & boost technological advancements, EAST-NMR
- (77) Epigenetic and genome stability: Non coding RNA-mediated chromatin modifications in *S. cerevisiae*, EPINCRNA
- (78) Epigenetic determinants of the genome that govern cellular plasticity, EPIGEPLAS
- (79) Epigenetic regulation and monoallelic gene expression: the X-inactivation paradigm and beyond, EPIGENETIX
- (80) Epigenetic regulation of the adaptative response of *C.reinhardtii* to development and environmental stresses: Characterization of Histone PTMS, gene regulation and pathways employing a Systems Biology., EPISYSBIOL
- (81) Epigenetics towards systems biology, EPIGENESYS
- (82) Eukaryotic unicellular organism biology systems biology of the control of cell growth and proliferation, UNICELLSYS
- (83) European consortium on synaptic protein networks in Neurological and Psychiatric diseases, EUROSPIN
- (84) European multidisciplinary ALS network identification to cure motor neuron degeneration, EURO-MOTOR
- (85) European Sequencing and Genotyping Infrastructure, ESGI
- (86) Events, Causality and Symmetry-the next-generation semantics, ECSYM

- (87) Evolution and Development of Bacterial Communication, EVODEVOQUORUM
- (88) Evolution of gene regulatory networks in animal development, EVONET
- (89) Exploitation of actinomycetes genomics using synthetic and system biology approaches, EXPLOGEN
- (90) Exploring cellular dynamics at nanoscale, EXCELL
- (91) Expression regulatory networks: beyond promoters and transcription control, ERNBPTC
- (92) Fighting osteoporosis by blocking nucleotides: purinergic signalling in bone formation and homeostasis, ATPBONE
- (93) Finding biomarkers of anti-microbial drug resistance via a systems biology analysis of fungal pathogen interactions with the human immune system, SYBARIS
- (94) From Data to Models: New Bioinformatics Methods and Tools for Data-Driven Predictive Dynamic Modelling in Biotechnological Applications, BIOPREDYN
- (95) Functional and evolutionary studies of the glutamatergic synapse; a proteomic and genetic approach, PSIEMBL
- (96) Functional and regulatory protein networks of chromatin modifying enzymes, CHROMATINMODWEB
- (97) Functional genomics of fatty acid desaturases in *Caenorhabditis elegans*, FUNGENCEL
- (98) Fungi in the setting of inflammation, allergy and autoimmune diseases: Translating basic science into clinical practices, ALLFUN
- (99) GENE REGULATORY NETWORK CONTROLLING THE ROOT STEM CELL NICHE IN *Arabidopsis thaliana*, STEM CELL REGULATION
- (100) Genetic and epigenetic determinants of allele-specific gene expression in the human Major Histocompatibility Complex, REGVARMHC
- (101) Genetic and Epigenetic Networks in Cognitive Dysfunction, GENCODYS
- (102) Genetic interaction networks: From *C. elegans* to human disease, 2-HIT
- (103) Genetics of Resistance to Malaria Parasites in the Mosquito *Anopheles gambiae*, MALARES
- (104) Genome Evolution in the Animal Kingdom, GENEVA
- (105) Genomic determinants of inflammation: from physical measurements to system perturbation and mathematical modeling, MODEL-IN
- (106) Genomics biomarkers of environmental health, ENVIROGENOMARKERS
- (107) Harnessing systems immunology to unravel dendritic cell subset biology, SYSTEMSDENDRITIC
- (108) High Throughput Systematic Single Cell Genomics using Micro/Nano-Fluidic Chips for Extracting, Pre-analysing, Selecting and Preparing Sequence-ready DNA, CELL-O-MATIC
- (109) How biochemical networks encode biological specificity: Modulation of cell migration by isoform specific ERK and Akt signaling, BIOSPEC

- (110) How does the X chromosome regulate DNA methylation in pluripotent stem cells?, XXDNAM
- (111) Human Evolutionary Immunogenomics: population genetic variation in immune responses, EVOIMMUNOPOP
- (112) Human Genetics of Tuberculosis, GENTB
- (113) Identification and characterization of primate structural variation and an assessment of intra-specific patterns of selection and copy-number variation, PRIMATESVS
- (114) Identifying network control elements in breast cancer oncogenic transformation via whole transcriptome analysis, CONTROLNETONCTTRANS
- (115) Improving the resistance of legume crops to combined abiotic and biotic stress, ABSTRESS
- (116) In-depth quantification and characterisation of PI 3-kinase signalling networks at a System Biology level, PI3K SYSTEMS BIOLOGY
- (117) Industrial Systems Biology of Yeast and *A. oryzae*, INSYSBIO
- (118) Inferring DNA binding specificities through in silico folding of natively unstructured protein regions, PROTDNABINDSPEC
- (119) Initiating and interfering with silencing of transposons, I2ST
- (120) INtegral BIOmathics Support Action, INBIOA
- (121) Integrated evolutionary analyses of genetic and drug interaction networks in yeast, NETWORK EVOLUTION
- (122) Integrating modeling into plant systems biology: Applications to auxin-driven plant morphogenesis, PLANTSYSMODEL
- (123) INTEGRATION OF THE SYSTEM MODELS OF INSULIN SIGNALLING AND OF MITOCHONDRIAL FUNCTION AND ITS APPLICATION IN THE STUDY OF COMPLEX DISEASES, MITIN
- (124) Interferon-focused Innate Immunity Interactome and Inhibitome, I-FIVE
- (125) International Data Exchange and Data Representation Standards for Proteomics, PROTEOMEXCHANGE
- (126) KRAB zinc finger gene biology in evolution and disease, KRAB-ZNF
- (127) Linking the clock to metabolism, TIMET
- (128) Lipid droplets as dynamic organelles of fat deposition and release: Translational research towards human disease, LIPIDOMICNET
- (129) Macrophage systems biology applied to disease control, MACROSYS
- (130) Mammalian Origin of replication Genome-wide Mapping and Regulation, ORIGINOME
- (131) Mapping the cell, MAPPING THE CELL
- (132) Mechanisms of Epigenetic regulation in Development, Evolution and Adaptation, MEDEA
- (133) Mechanisms of microRNA biogenesis and turnover, MIRTURN
- (134) Mechanisms of the Development of ALLergy, MEDALL
- (135) MEIOtic inSIGHT: Deciphering the engine of heredity, MEIOSIGHT
- (136) Metabolic Flux Analysis and Cancer, METAFLUX

- (137) Metabolomics of fungal diseases: a systems biology approach for biomarkers discovery and therapy, FUNMETA
- (138) Metabolomics of single eukaryotic cells, MESEL
- (139) Methods for high-throughput (HTP) analysis of protein glycosylation, HIGHGLYCAN
- (140) Microbes in Allergy and Autoimmunity Related to the Skin, MAARS
- (141) Microsystems and Bioanalysis Platforms for Health Care MICROCARE, MICROCARE
- (142) Modelling and simulation environment for systems medicine (Chronic obstructive pulmonary disease -COPD- as a use case), SYNERGY-COPD
- (143) Modelling latent causes in molecular networks, LATENTCAUSES
- (144) Models of genome evolution, phylogenomics and the tree of life, PHYGENOM
- (145) Modulating cellular clearance to cure human disease, CLEAR
- (146) Molecular mechanisms controlling X chromosome inactivation, ACTIVATION OF XCI
- (147) Molecular mechanisms underlying plant miRNA action, MICROMECCA
- (148) Molecular signatures: a systems biology tool to understand how leaf development is constrained by drought, MOLSIG
- (149) Multi-layer network modules to identify markers for personalized medication in complex diseases, MULTIMOD
- (150) Multilevel Modelling for Predictive Toxicology, COMPTOX
- (151) Multiscale Applications on European e-Infrastructures, MAPPER
- (152) Multiscale poro-micromechanics of bone materials, with links to biology and medicine, MICROBONE
- (153) New Algorithms for Host Pathogen Systems Biology, SYSPATHO
- (154) Optimization and inference algorithms from the theory of disordered systems: theoretical challenges and applications to large-scale inverse problems in systems biology, OPTINF
- (155) Pathogenomics and systems biology of fungal infections an integrative approach, FINSYSB
- (156) Physical principles in host-pathogen interactions, PPHPI
- (157) Polycomb in development, genome regulation and cancer, FLYINGPOLYCOMB
- (158) Population transcriptional genomics in humans using high throughput sequencing, POPRNASEQ
- (159) Practical statistical approaches for addressing replicability problems in life sciences, PSARPS
- (160) Predicting long-term toxic effects using computer models based on systems characterization of organotypic cultures, NOTOX
- (161) Principles of Chromatin Organization, CHROMATINPRINCIPLES
- (162) Programmed and unprogrammed genomic rearrangements during the evolution of yeast species, CHROMARRANGE

- (163) Prokaryotic RNomics: Unravelling the RNA-mediated regulatory layers, PROKRNA
- (164) Protease Systems Biology in Tumorigenesis and Neurodegeneration, PROTEASYS
- (165) Proteomics facility at the institute of molecular biology and biotechnology, PROFI
- (166) Proteomics specification in time and space, PROSPECTS
- (167) Proteomics standards international molecular exchange – Systematic capture of published molecular interaction data, PSIMEX
- (168) Proteomics v3.0: development, implementation and dissemination of a third generation proteomics technology, PROTEOMICS V3.0
- (169) Quantitative Analysis of the Hourglass Model of Evolution of Development., HOURGLASS
- (170) Quantitative Reactive Modeling, QUAREM
- (171) Quantitative understanding of a living system and its engineering as a cellular organelle, CELLDOCTOR
- (172) Rational design of plant systems for sustainable generation of value-added industrial products, SMARTCELL
- (173) Real-time non-invasive characterization and selection of oil-producing microalgae at the single-cell level, FUEL MAKING ALGAE
- (174) Regulating recombination in mitotic and meiotic cells, RECMITMEI
- (175) Regulation and function of non-coding RNAs in epigenetic processes: the paradigm of X-chromosome inactivation, NCRNAX
- (176) Regulation of Polycomb Complex (PRC2) during development and in diseases, REPODDID
- (177) Regulatory genomics in Drosophila, REGULATORY GENOMICS
- (178) Relevance of double strand break repair pathway choice in human disease and cancer, DSBRECA
- (179) Reproductive Biology Early Research Training, REPRO-TRAIN
- (180) RNA and epigenetics: RNAi-driven chromatin modifications, RNAIEPIMOD
- (181) RNA silencing in regulation and evolution, REVOLUTION
- (182) RNAi-mediated genome regulation, RNAIGENREG
- (183) Role of bone morphogenic protein 8b (BMP8b) in thermogenesis, BMP 8B THERMOGENESIS
- (184) Sex-biased genome and transcriptome evolution in mammals, SEXGENTRANSEVOLUTION
- (185) Signaling circuitry controlling fungal virulence: identification and characterization of conserved and specific fungal virulence genes as common antifungal targets, ARIADNE
- (186) Signaling Networks of Ovarian Cancer Metastases, Stem Cells and Maturation Phenotypes, SIGNALING METASTATES
- (187) Single cell imaging of gene activation during oxidative neuron death: towards quantitative systems approaches, SIM-ON

- (188) Single-cell gene regulation in differentiation and pluripotency, SINGLE-CELL GENOMICS
- (189) Small RNA mediated Epigenetics in vertebrates, EPIRNAS
- (190) Social interactions in microbes, INTERACTINGMICROBES
- (191) Sphingolipid homeostasis: from basic biology to applications, SPHINGONET
- (192) sRNA regulatory networks, MIRNET
- (193) Strengthening the University of Plovdiv research potential in plant systems biology and food biotechnology, BIOSUPPORT
- (194) Sustainable approaches to reduce Oomycete (Saprolegnia) infections in aquaculture, SAPRO
- (195) Synaptic Systems: dissecting brain function in health and disease, SYNSYS
- (196) Synthetic metabolic pathways for carbon fixation, SYMPAC
- (197) System biology of nitrogen-carbon-signal integration in the overall Arabidopsis signaling network, ATSYSTEM-BIOL
- (198) Systematic analysis of factors controlling meiotic recombination in higher plants, MEIOSYS
- (199) Systematic chemical genetic interrogation of biological networks, SCG
- (200) Systems analysis of plant metabolism through the integration of heterogeneous data from genetics, informatics and metabolomics, SAMIT
- (201) Systems and Signals Tools for Estimation and Analysis of Mathematical Models in Endocrinology and Neurology, SYSTEAM
- (202) Systems biology approaches to novel Tumour Suppressors, SYSTUMS
- (203) Systems biology approaches to understand cell pluripotency Acronym: PluriSys, PLURISYS
- (204) Systems Biology as a Driver for Industrial Biotechnology, SYSINBIO
- (205) Systems Biology of Cancer Kinome, CANCER KINOME
- (206) Systems Biology of Colorectal Cancer, SYSCOL
- (207) Systems biology of human metabolism, SYSTEM_US
- (208) Systems Biology of Lipids Metabolism, SBLIME
- (209) Systems biology of liver cancer: an integrative genomic-epigenomic approach, MODHEP
- (210) Systems Biology of Mitosis, MITOSYS
- (211) Systems biology of Mycobacterium tuberculosis, SYSTEMTB
- (212) Systems biology of phagosome formation and maturation, modulation by intracellular pathogens, PHAGOSYS
- (213) Systems Biology Of Pseudomonas Aeruginosa In Biofilms, SYSBIOFILM
- (214) Systems Biology of Stem Cells and Reprogramming, SYBOSS
- (215) Systems biology of T-cell activation in health and disease, SYBILLA
- (216) Systems biology of the heterobasidion-spruce interaction: application of metabolomics and genomics to understanding host resistance, SYBHES

- (217) Systems biology to understand plant architecture, SYSARC
- (218) Systems biology towards novel chronic kidney disease diagnosis and treatment, SYSKID
- (219) Systems Chemical Biology – Chemical Biological Perturbation and Dissection of Dynamic Biological Systems, SYSCHEMBIOL
- (220) Systems Chemistry from Bottom Up: Switching, Gating and Oscillations in Non Enzymatic Peptide Networks, BOTTOM-UP_SYSCHEM
- (221) Systems Genetics of Heritable variations, SIGHT
- (222) Systems Genetics of Obesity and Related Metabolic Traits in Pig Model to Improve Human Health, SYSGEN OF OBESITY
- (223) Systems microscopy ? a key enabling methodology for next-generation systems biology, SYSTEMS MICROSCOPY
- (224) 'Systems' study of cellular growth, shape and polarity, SYSGRO
- (225) Systems-level, multi-layer understanding of cellular responses to ionizing radiation, TRIREME
- (226) System-wide analysis of regulatory processes that mediate at the boarder of metabolome and proteome, METABOLICREGULATORS
- (227) Tackling the future challenges in systems biology, FUTURESYSBIO
- (228) Targeting endothelial metabolism: a novel anti-angiogenic therapy, ECMETABOLISM
- (229) Targeting glucocorticoid resistance in T-ALL: a Systems Biology approach, TIGRE
- (230) Targeting the reproductive biology of the malaria mosquito *Anopheles gambiae*: from laboratory studies to field applications, ANOREP
- (231) Telomere function in meiosis, TELOMERES IN MEIOSIS
- (232) The Application of Modern Proteomic and Metabolomic Methodologies to the Assessment of FOOD SAFETY, FOOSAF
- (233) The biological role of tandem repeats as hypervariable modules in genomes, REPEATSASMUTATORS
- (234) The consolidation of systems biology research stimulating the widespread adoption of systems approaches in biomedicine, biotechnology, and agri-food, ERASYSBIO+
- (235) The evolution of antibiotic resistance: integrating molecular mechanisms of resistance and evolutionary context, RESISTEVO
- (236) The evolution of genetic robustness, 2B-ROBUST
- (237) The international data coordination centre, I-DCC
- (238) THE ROLE OF BACTERIAL MULTIGENE FAMILIES IN INFECTION: IDENTIFICATION OF HOST TARGET NETWORKS BY HIGH-THROUGHPUT PROTEIN INTERACTOMICS, INFBIOSYS
- (239) The role of heterochromatin enzymes on the biology of their targets, PICHV2.0
- (240) The role of noncoding RNA in sense and antisense or orientation in epigenetic control of rRNA genes, RIBOGENES

- (241) The role of the Calcium Sensing Receptor (CaSR) in health and disease, implications for translational medicine., MULTIFACETED CASR
- (242) The tympanal ears of insects: structural solutions to acoustic signal analysis., INSECT EARS
- (243) Towards the establishment of a permanent European Virtual Institute dedicated to Malaria Research (EVIMalaR), EVIMALAR
- (244) Traditional Chinese medicine in the post-genomic era: identifying lead therapeutic compounds against cancer, TCMCANCER
- (245) Training in systems biology applied to flowering, SYSFLO
- (246) Transcription factor dynamics in living cells at the single molecule level, TF DYNAMICS IN VIVO
- (247) Transcriptomics in cancer epidemiology, TICE
- (248) Transport and signalling in Polarized Cells, TRANSPOL
- (249) Uncovering and understanding RNA through Massively Parallel Sequencing, RNA-MAPS
- (250) Uncultivated microbes in situ – a computational biology approach to determine molecular capabilities and ecological roles, UMICIS
- (251) Understanding the axon-glial functional unit in myelination and remyelination, AXOGLIA
- (252) Understanding the cytotoxicity of aberrantly folded proteins in neurodegeneration, FOLDTOX
- (253) United Europeans for the development of pharmacogenomics in multiple sclerosis, UEPHA-MS
- (254) Unveiling the Roles of Chromatin Insulators in Higher-order Chromatin Architecture and Transcription Regulation one molecule at a time., SMINSULATOR
- (255) Variability and robustness in bio-molecular systems, VARB
- (256) VIB International Postdoctoral Program to boost '-omics' technologies throughout the institute., OMICS@VIB
- (257) Virtual multidisciplinary EnviroNments USing Cloud infrastructures, VENUS-C
- (258) Word Wide NMR, WW-NMR
- (259) Zebrafish Regulomics for Human Health, ZF-HEALTH

A.2 Co-authorship networks of systems biology researchers in Austria and internationally

Systems biology researchers based in Austria with publications on topic ‘systems biology’ in Web of Knowledge™ database since 2000 (as of August 2011)

- | | |
|-----------------------------|----------------------------|
| (1) Bollenbach, Tobias | (21) Mechtler, Karl |
| (2) Dehmer, Matthias | (22) Mühlberger, Irmgard |
| (3) Deigner, Hans-Peter | (23) Noe, Christian |
| (4) Drack, Manfred | (24) Osprian, Ingrid |
| (5) Engl, Heinz W. | (25) Perco, Paul |
| (6) Enot, David P. | (26) Rattei, Thomas |
| (7) Flamm, Christoph | (27) Schleper, Christa |
| (8) Graber, Armin | (28) Schmeiser, Christian |
| (9) Grabherr, Reingard | (29) Schuster, Peter |
| (10) Guet, Calin | (30) Stark, Alexander |
| (11) Henzinger, Thomas A. | (31) Superti-Furga, Giulio |
| (12) Hirt, Heribert | (32) Torgersen, Helge |
| (13) Hofacker, Ivo L. | (33) Trajanoski, Zlatko |
| (14) Koal, Therese | (34) Weckwerth, Wolfram |
| (15) Kreil, David P. | (35) Weinberger, Klaus M. |
| (16) Kuchler, Karl | (36) Widder, Stefanie |
| (17) Kugler, Philipp | (37) Wienkoop, Stefanie |
| (18) Lu, James | (38) Wiesinger, Martin |
| (19) Mayer, Bernd | (39) Zacherl, Nikolaus |
| (20) Mechtcheriakova, Diana | (40) Zatloukal, Kurt |

Top 100 systems biology researchers with publications on topic ‘systems biology’ in Web of Knowledge™ database since 2000 (as of August 2011)

The list of authors has been scanned for inconsistencies in names. Additionally, following names were excluded because they are shared by several authors: Anonymous, Zhang J, Chen X, Kim S, Yang Jy, Li J, Brown M, Wang Y.

- | | |
|------------------------------|--------------------------|
| (1) Aderem, Alan | (13) Banga, Julio R. |
| (2) Aebersold, Ruedi | (14) Bolouri, Hamid |
| (3) Alberghina, Lilia | (15) Breitling, Rainer |
| (4) Allgöwer Frank | (16) Bruggeman, Frank J. |
| (5) Alon, Uri | (17) Burgess, Shane C. |
| (6) An, Gary | (18) Califano, Andrea |
| (7) Andersen, Melvin E. | (19) Cascanta, Marta |
| (8) Androulakis, Ioannis, P. | (20) Chen, Bor-Sen |
| (9) Auffray, Charles | (21) Chen Luonan |
| (10) Bader, Gary D. | (22) Cho, Kwang Hyun |
| (11) Bakker, Barbara M. | (23) Clermont, Gilles |
| (12) Baliga, Nitin S. | (24) Collins, James J. |

- (25) Deutsch, Eric W.
- (26) Doyle, Francis J. III
- (27) Dunn, Warwick B.
- (28) Fages, Francois
- (29) Fernie, Alisdair R.
- (30) Ghosh, Samik
- (31) Gilles, Ernst Dieter
- (32) Goodacre, Royston
- (33) Hankemeier, Thomas
- (34) Heinemann, Matthias
- (35) Hogenesch, John B.
- (36) Holmes, Elaine
- (37) Hood, Leroy E.
- (38) Hucka, Michael
- (39) Hunt, C. Anthony
- (40) Iyengar, Ravi
- (41) Kell, Douglas B.
- (42) Khammash, Mustafa
- (43) Kim, Tae Yong
- (44) Kitano, Hiroaki
- (45) Klamt, Steffen
- (46) Klingmüller, Ursula
- (47) Klipp, Edda
- (48) Kochhar, Sunil
- (49) Kolch, Walter
- (50) Kopka, Joachim
- (51) Lauffenburger, Douglas A.
- (52) Le Novère Nicholas
- (53) Lee, Sang Yup
- (54) Liao, James C.
- (55) Lindon, John C.
- (56) Lu, Xin
- (57) Ma'ayan, Avi
- (58) Matsuoka, Yukiko
- (59) Mendes, Pedro
- (60) Miyano, Satoru
- (61) Murphy, Robert F.
- (62) Nicholson, Jeremy K.
- (63) Nielsen, Jens
- (64) Noble, Denis
- (65) Oliver, Stephen G.
- (66) Oresic, Matej
- (67) Palsson, Bernhard O.
- (68) Pandey, Akhilesh
- (69) Popel, Aleksander S.
- (70) Priami, Corrado
- (71) Roukos, Dimitrios H.
- (72) Saez-Rodriguez, Julio
- (73) Saito, Kazuki
- (74) Sander, Chris
- (75) Sauer, Uwe
- (76) Sauro, Herbert M.
- (77) Schadt, Eric E.
- (78) Selbig, Joachim
- (79) Snoep, Jacky L.
- (80) Soliman, Sylvain
- (81) Spasic, Irena
- (82) Subramaniam, Shankar
- (83) Tarnok, Attila
- (84) Terzic, Andre
- (85) Timmer, Jens
- (86) Tomita, Masaru
- (87) Ueda, Hiroki R.
- (88) Van der Greef, Jan
- (89) Van Ommen, Ben
- (90) Vera, Julio
- (91) Vidal, Marc
- (92) Vodovotz, Yoram
- (93) Voit, Eberhard O.
- (94) Weckwerth, Wolfram
- (95) Westerhoff, Hans V.
- (96) Wiechert, Wolfgang
- (97) Willmitzer, Lothar
- (98) Wolkenhauer, Olaf
- (99) Xu, Guowang
- (100) Zhang, Xiang-S